USER'S MANUAL

NEC

"SUPERCAP"

(Electric Double-Layer Capacitors)

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UP TO 2 200 000 MICROFARAD, SMALL, BATTERY-LIKE CAPACITORS THAT CAN PROTECT CIRCUITS AGAINST TEMPORARY POWER SHUT-DOWNS

The expanding use of digital processing with its associated memory is driving the need for a standby power source to maintain the contents of volatile memories or to continue processing function during AC power outages. Historically, this standby function has been a choice between primary or secondary batteries.

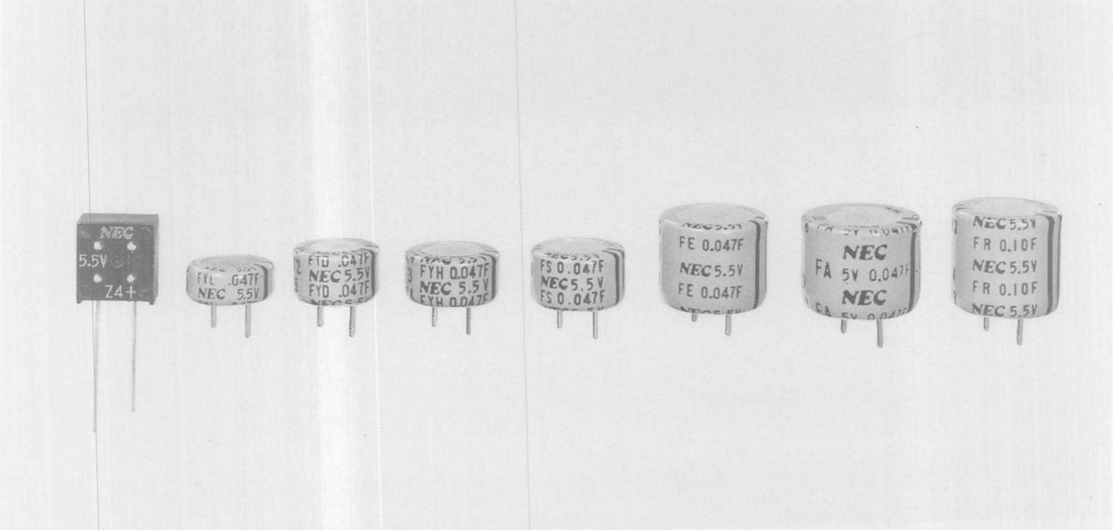
The use of nonrechargeable (primary) batteries, such as Lithium, may be risky since there is no way to determine how much charge is still available to handle a power outage of unknown duration. Rechargeable batteries, such as Ni-Cd must have a controlled charge rate to limit current to battery, and must be periodically replaced.

More recently, the use of CMOS and other low power drain technologies in processor and memory IC's has drastically reduced the total standby power requirements. This coupled with the fact that most power outages last only a short period of time (order of several hours) has opened the door for the **SUPERCAP** as a third alternative standby power source.

SUPERCAP is a completely innovative type of capacitor providing a volumetric efficiency (capacitance per unit volume of a given voltage) of 10 to 50 times that of conventional aluminum electrolytic capacitors. The high capacitance (2 200 000 microfarads) and low leakage current makes the **SUPERCAP** an efficient, reliable, and cost effective energy storage device. **SUPERCAP** can be used as standby power sources for CMOS memories and microcomputers up to several weeks during power outages.

The **SUPERCAP** can be assembled on printed circuit boards by conventional soldering processes together with all other components. The **SUPERCAP** can be charged and discharged at both high and low current rates; i.e., microamps to amps.

This brochure tells the SUPERCAP story.



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1. FEATURES

1.1 Extremely High Volumetric Efficiency

The capacitance per unit area of the electric double layer is estimated as high as 20 to 40 μF/cm^2. The surface area of the activated carbon is around 10,000,000 cm^2 per gram. Consequently, one gram of activated carbon particles can be calculated to provide 200 to 400 F of capacitance.

This is why **SUPERCAP** has extremely high capacitance value in such a small package.

1.2 Simple Installation and Maintenance Free

As the **SUPERCAP** is a capacitor, there is no problem with charging/discharging no matter how quickly or how frequently it is conducted. Unlike Ni-Cd batteries, there need neither specific charging circuit nor troublesome charging conditions.

1.3 Wide Operating Temperature Range

The operating temperature range of **SUPERCAP** is wider than battery's. (FR: $-40\,^\circ$C to $+85\,^\circ$C, FE: $-40\,^\circ$C to $+70\,^\circ$C, others: $-25\,^\circ$C to $+70\,^\circ$C)

Operation at higher temperature on continuous basis will result in a decrease in capacitance. That means the backup time capability will be reduced.

1.4 "Open" Failure Mode

The failure mode of conventional capacitors is generally characterized by "short", but in case of **SUPERCAP,** it becomes "open" only when excess voltage and/or temperature has been impressed for a long time period, resulting in gassing from electrolyte and losing electrical contact between carbon particles and electroconductive rubber. Explosion by gassing can not happen because of very low content of electrolyte in unit cells.

1.5 Long Life

On top of its low content of electrolyte, the simple product structure and the hermeticity of unit cells promise a longer life for **SUPERCAP** in comparison with conventional aluminum electrolytic capacitors.

1.6 Taping Package for Automatic Assembly

Resin molded type has been developed as the FM series which is deliverable with the taping package for automatic assembly.

1.7 Extention to Specific Range of Rated Voltages for Specific Applications

In pursuit of total performance of the circuit, other line-up in specific rated voltages have been required very often for a few years.

For responding to those requirements, NEC has standardized the 3.5 V and 6.5 V series as the extention to new direction.

NEC's line-up in rated voltage, therefore, consists of 3.5 V, 5.5 V, 6.5 V and 11 V.

With the features mentioned above, the **SUPERCAP** can be ranked as a device between a battery and a capacitor. Once **SUPERCAP** is designed in, you can be free from power interruptions or battery maintenance in your systems with microcomputers/C MOS memories.

2. ORDERING INFORMATION

2.1 Catalog Numbering System

FYD 0H 105 Z

- Z — Capacitance tolerance; $^{+80}_{-20}$ %
- 105 — Capacitance;
  First two digits represent significant figures. 3rd digit specifies number of zeros to follow. Microfarad code.
- 0H — Max rated voltage
  - 0V : 3.5 V
  - 0H : 5.5 V
  - 0J : 6.5 V
  - 1A : 11 V (FA Series)
- FYD — Super capacitor;
  - FA : FA Series
  - FE : FE Series
  - FS : FS Series
  - FR : FR Series
  - FYD : FY Series (Small-diameter type)
  - FYH : FY Series (Low-height type)
  - FYL : FY Series (Very low height type)
  - FM : FM Series (Molded type)

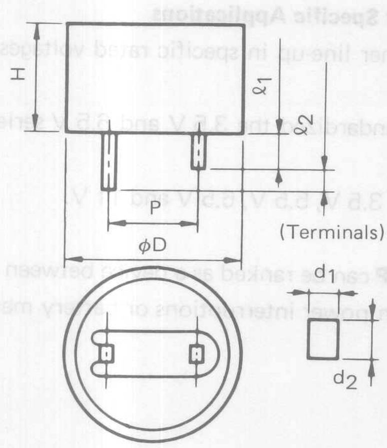
Following on this catalog numbering in bulk, taping specification numbering for FM series is undermentioned.

TP 16

- 16 — Height of component from tape center (16: 16 mm, 18: 18 mm)
- TP — Tape packaging

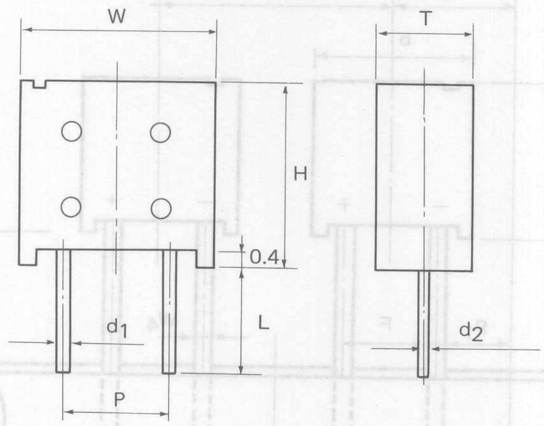
2.2 Outline Drawing (unit in mm)

- Can Case Type (FA, FE, FS, FR, FY Series)

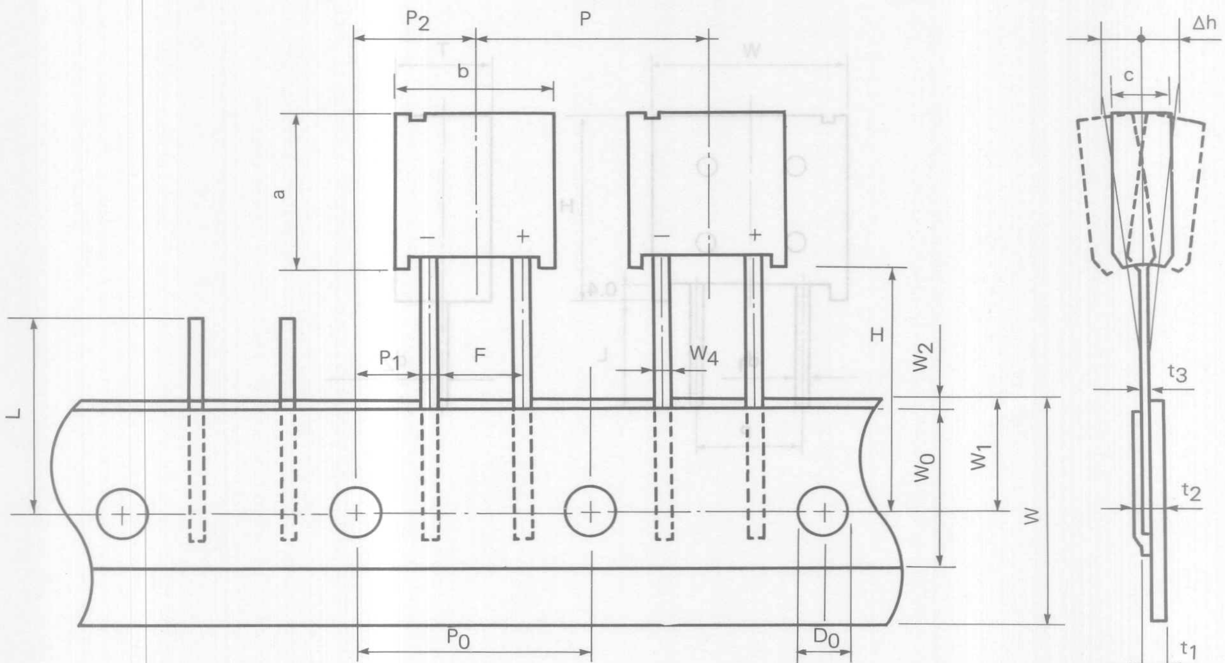


ℓ_2: 2 MAX : FA Series
0.3 MIN : FE, FS, FR, FY Series

- Molded Type (FM Series)



2.3 Taping Specification (Ammo pack, Applicable only for FM Series)



Unit in mm

Item	Symbol	Value	Tolerance	Remarks
Component Height	a	11.5	± 0.5	
Component Width	b	10.5	± 0.5	
Component Thickness	c	*	± 0.5	* 5.0 for 0.01 F to 0.047 F, 6.5 for 0.1 F
Lead-wire Width	W_4	0.5	± 0.1	
Lead-wire Thickness	t_3	0.4	± 0.1	
Pitch of Component	P	12.7	± 1.0	
Sprocket pitch	P_0	12.7	± 0.3	
Sprocket hole center to lead	P_1	3.85	± 0.7	
Sprocket hole to component center	P_2	6.35	± 1.3	
Lead spacing	F	5.0	± 0.5	
Component Alignment	Δh	2.0 MAX.	–	
Tape width	W	18.0	$^{+1.0}_{-0.5}$	
Hold-down tape width	W_0	12.5 MIN.	–	
Sprocket hole position	W_1	9.0	± 0.5	
Hold-down tape position	W_2	3.0 MAX.	–	
Height of component from tape center	H	16.0	± 0.5	
		18.0	± 0.5	
Sprocket hole diameter	D_0	ϕ4.0	± 0.2	
Total tape thickness	t_1	0.7	± 0.2	
	t_2	1.5 MAX.	–	
Length of shipped lead	L	11 MAX.	–	

3. STANDARD PRODUCTS

3.1 FA Series

Catalog NBR	Cap. (Farad)	MAX. Rated Voltage (V. DC)	MAX. ESR (Ω at 1 kHz)	MAX. Ia (mA)	Dimensions mm (inch) D ± 0.5	H MAX.	P ± 0.3	d_1 ± 0.1	d_2 ± 0.1	ℓ_1 MAX.	Weight g (oz)
FA0H473Z	0.047	5.5	20	0.071	16.0 (0.630)	15.5 (0.610)	5.1 (0.2)	0.4 (0.016)	1.2 (0.047)	5.0 (0.197)	6.2 (0.219)
FA0H104Z	0.1	5.5	8	0.15	21.5 (0.846)	15.5 (0.610)	7.6 (0.3)	0.6 (0.024)	1.2 (0.047)	5.5 (0.217)	12 (0.423)
FA0H224Z	0.22	5.5	5	0.33	28.5 (1.122)	16.5 (0.650)	10.2 (0.4)	0.6 (0.024)	1.4 (0.055)	9.5 (0.374)	25 (0.882)
FA0H474Z	0.47	5.5	3.5	0.71	36.5 (1.437)	16.5 (0.650)	15 (0.591)	0.6 (0.024)	1.7 (0.067)	9.5 (0.374)	42 (1.482)
FA0H105Z	1.0	5.5	2.5	1.5	44.5 (1.752)	18.5 (0.728)	20 (0.787)	1.0 (0.039)	1.4 (0.055)	9.5 (0.374)	65 (2.293)
FA1A223Z	0.022	11	20	0.066	16.0 (0.630)	25.0 (0.984)	5.1 (0.2)	0.4 (0.016)	1.2 (0.047)	5.0 (0.197)	7.5 (0.265)
FA1A104Z	0.1	11	8	0.3	28.5 (1.122)	25.5 (1.004)	10.2 (0.4)	0.6 (0.024)	1.4 (0.055)	9.5 (0.374)	32 (1.129)
FA1A224Z	0.22	11	6	0.66	36.5 (1.437)	27.5 (1.083)	15 (0.591)	1.0 (0.039)	1.4 (0.055)	9.5 (0.374)	55 (1.940)
FA1A474Z	0.47	11	4	1.41	44.5 (1.752)	28.5 (1.122)	20 (0.787)	1.0 (0.039)	1.4 (0.055)	9.5 (0.374)	83 (2.928)

Note 1) Capacitance tolerance: +80 %, −20 %; 2) Weight is typical.

3.2 FE Series

Catalog NBR	Cap. (Farad)	MAX. Rated Voltage (V. DC)	MAX. ESR (Ω at 1 kHz)	MAX. Ia (mA)	Dimensions mm (inch) D ± 0.5	H MAX	P ± 0.5	d_1 ± 0.1	d_2 ± 0.1	ℓ_1 MIN.	Weight g (oz)
FE0H473Z	0.047	5.5	14	0.071	14.5 (0.57)	14.0 (0.55)	5.1 (0.2)	0.4 (0.016)	1.2 (0.047)	2.2 (0.087)	1.2 (0.042)
FE0H104Z	0.1	5.5	6.5	0.15	16.5 (0.65)	14.0 (0.55)	5.1 (0.2)	0.4 (0.016)	1.2 (0.047)	2.7 (0.106)	5 (0.177)
FE0H224Z	0.22	5.5	3.5	0.33	21.5 (0.85)	15.5 (0.61)	7.6 (0 3)	0.6 (0.024)	1.2 (0.047)	3.0 (0.118)	9.5 (0.336)
FE0H474Z	0.47	5.5	1.8	0.71	28.5 (1.12)	16.5 (0.65)	10.2 (0.4)	0.6 (0.024)	1.4 (0.055)	6.1 (0.240)	16 (0.565)
FE0H105Z	1.0	5.5	1.0	1.5	36.5 (1.44)	18.5 (0.73)	15.0 (0.59)	0.6 (0.024)	1.7 (0.067)	6.1 (0.240)	38 (1.343)
FE0H155Z	1.5	5.5	0.6	2.3	44.5 (1.75)	18.5 (0.73)	20.0 (0.79)	1.0 (0.039)	1.4 (0.055)	6.1 (0.240)	72 (2.544)

Note 1) Capacitance tolerance: +80 %, −20 %; 2) Weight is typical.

3.3 FS Series

Catalog NBR	Cap.	MAX. Rated Voltage	MAX. ESR	MAX. Ia	Dimensions mm (inch)						Weight
	(Farad)	(V. DC)	(Ω at 1 kHz)	(mA)	D ± 0.5	H MAX.	P ± 0.5	d_1 ± 0.1	d_2 ± 0.1	ℓ_1 MIN.	g (oz)
FS0H223Z	0.022	5.5	60	0.033	11.5 (0.453)	8.5 (0.335)	5.08 (0.200)	0.4 (0.016)	1.2 (0.047)	2.7 (0.106)	1.6 (0.057)
FS0H473Z	0.047	5.5	40	0.071	13.0 (0.512)	8.5 (0.335)	5.08 (0.200)	0.4 (0.016)	1.2 (0.047)	2.2 (0.087)	2.6 (0.092)
FS0H104Z	0.1	5.5	25	0.15	16.5 (0.650)	8.5 (0.335)	5.08 (0.200)	0.4 (0.016)	1.2 (0.047)	2.7 (0.106)	4.1 (0.145)
FS0H224Z	0.22	5.5	25	0.33	16.5 (0.650)	13.0 (0.512)	5.08 (0.200)	0.4 (0.016)	1.2 (0.047)	2.7 (0.106)	5.3 (0.187)
FS0H474Z	0.47	5.5	13	0.71	21.5 (0.846)	13.0 (0.512)	7.62 (0.300)	0.6 (0.024)	1.2 (0.047)	3.0 (0.118)	10 (0.353)
FS0H105Z	1.0	5.5	7	1.5	28.5 (1.122)	14.0 (0.551)	10.16 (0.400)	0.6 (0.024)	1.4 (0.055)	6.1 (0.240)	18 (0.635)

Note 1) Capacitance tolerance: +80 %, −20 %; 2) Weight is typical.

3.4 FR Series

Catalog NBR	Cap.	MAX. Rated Voltage	MAX. ESR	MAX. I_a	MIN. SD	Dimensions mm (inch)						Weight
	(Farad)	(V. DC)	(Ω at 1 kHz)	(mA)	(V)	D ± 0.5	H MAX.	P ± 0.5	d_1 ± 0.1	d_2 ± 0.1	ℓ_1 MIN.	g (oz)
FR0H223Z	0.022	5.5	220	0.033	4.2	11.5 (0.453)	14.0 (0.551)	5.08 (0.200)	0.4 (0.016)	1.2 (0.047)	2.7 (0.106)	2.3 (0.081)
FR0H473Z	0.047	5.5	110	0.071	4.2	14.5 (0.571)	14.0 (0.551)	5.08 (0.200)	0.4 (0.016)	1.2 (0.047)	2.4 (0.095)	3.9 (0.138)
FR0H104Z	0.1	5.5	150	0.15	4.2	14.5 (0.571)	15.5 (0.610)	5.08 (0.200)	0.4 (0.016)	1.2 (0.047)	2.4 (0.095)	4.3 (0.152)
FR0H224Z	0.22	5.5	180	0.33	4.2	14.5 (0.571)	21.0 (0.827)	5.08 (0.200)	0.4 (0.016)	1.2 (0.047)	2.4 (0.095)	5.3 (0.187)
FR0H474Z	0.47	5.5	100	0.71	4.2	16.5 (0.650)	21.5 (0.846)	5.08 (0.200)	0.4 (0.016)	1.2 (0.047)	2.7 (0.106)	7.5 (0.265)
FR0H105Z	1.0	5.5	60	1.5	4.2	21.5 (0.850)	22.0 (0.866)	7.62 (0.200)	0.6 (0.024)	1.4 (0.047)	3.0 (0.118)	13.3 (0.470)

Note 1) Capacitance tolerance: +80 %, −20 %; 2) Weight is typical.
3) SD: voltage holding characteristic.

3.5 FY Series

• FYD type: Small diameter

Catalog NBR	Cap. (Farad)	MAX. Rated Voltage (V. DC)	MAX. ESR (Ω at 1 kHz)	MAX. I_a (mA)	MIN. SD (V)	Dimensions mm (inch) D ± 0.5	H MAX.	P ± 0.5	d_1 ± 0.1	d_2 ± 0.1	ℓ_1 MIN.	Weight g (oz)
FYD0H223Z	0.022	5.5	220	0.033	4.2	11.5 (0.453)	8.5 (0.335)	5.08 (0.200)	0.4 (0.016)	1.2 (0.047)	2.7 (0.106)	1.6 (0.056)
FYD0H473Z	0.047	5.5	220	0.071	4.2	11.5 (0.453)	8.5 (0.335)	5.08 (0.200)	0.4 (0.016)	1.2 (0.047)	2.7 (0.106)	1.65 (0.058)
FYD0H104Z	0.1	5.5	100	0.15	4.2	13.0 (0.512)	8.5 (0.335)	5.08 (0.200)	0.4 (0.016)	1.2 (0.047)	2.2 (0.087)	2.4 (0.085)
FYD0H224Z	0.22	5.5	120	0.33	4.2	14.5 (0.571)	15.0 (0.591)	5.08 (0.200)	0.4 (0.016)	1.2 (0.047)	2.4 (0.095)	4.3 (0.152)
FYD0H474Z	0.47	5.5	65	0.71	4.2	16.5 (0.65)	15.0 (0.591)	5.08 (0.200)	0.4 (0.016)	1.2 (0.047)	2.7 (0.106)	6.0 (0.212)
FYD0H105Z	1.0	5.5	35	1.5	4.2	21.5 (0.85)	16.0 (0.629)	7.62 (0.300)	0.6 (0.024)	1.2 (0.047)	3.0 (0.118)	11.0 (0.388)
FYD0H145Z	1.4	5.5	45	2.1	4.2	21.5 (0.85)	19.0 (0.748)	7.62 (0.300)	0.6 (0.024)	1.2 (0.047)	3.0 (0.118)	12.0 (0.424)
FYD0H225Z	2.2	5.5	35	3.3	4.2	28.5 (1.122)	22.0 (0.866)	10.16 (0.400)	0.6 (0.024)	1.4 (0.055)	6.1 (0.240)	22.9 (0.809)

Note 1) Capacitance tolerance: +80 %, −20 %; 2) Weight is typical. 3) SD: voltage holding characteristic.

• FYH type: Low height

Catalog NBR	Cap. (Farad)	MAX. Rated Voltage (V. DC)	MAX. ESR (Ω at 1 kHz)	MAX. I_a (mA)	MIN. SD (V)	Dimensions mm (inch) D ± 0.5	H MAX.	P ± 0.5	d_1 ± 0.1	d_2 ± 0.1	ℓ_1 MIN.	Weight g (oz)
FYH0H223Z	0.022	5.5	200	0.033	4.2	11.5 (0.453)	7.0 (0.276)	5.08 (0.200)	0.4 (0.016)	1.2 (0.047)	2.7 (0.106)	1.5 (0.053)
FYH0H473Z	0.047	5.5	100	0.071	4.2	13.0 (0.512)	7.0 (0.276)	5.08 (0.200)	0.4 (0.016)	1.2 (0.047)	2.2 (0.087)	2.2 (0.078)
FYH0H104Z	0.1	5.5	50	0.15	4.2	16.5 (0.65)	7.5 (0.295)	5.08 (0.200)	0.4 (0.016)	1.2 (0.047)	2.7 (0.106)	3.4 (0.120)
FYH0H224Z	0.22	5.5	60	0.33	4.2	16.5 (0.65)	9.5 (0.374)	5.08 (0.200)	0.4 (0.016)	1.2 (0.047)	2.7 (0.106)	3.6 (0.127)
FYH0H474Z	0.47	5.5	35	0.71	4.2	21.5 (0.85)	10.0 (0.394)	7.62 (0.300)	0.6 (0.024)	1.2 (0.047)	3.0 (0.118)	7.2 (0.255)
FYH0H105Z	1.0	5.5	20	1.5	4.2	28.5 (1.122)	11.0 (0.433)	10.16 (0.400)	0.6 (0.024)	1.4 (0.055)	6.1 (0.240)	13.9 (0.491)

Note 1) Capacitance tolerance: +80 %, −20 %; 2) Weight is typical. 3) SD: voltage holding characteristic.

• FYL type: Very low height

Catalog NBR	Cap. (Farad)	MAX. Rated Voltage (V. DC)	MAX. ESR (Ω at 1 kHz)	MAX. I_a (mA)	MIN. SD (V)	Dimensions mm (inch) D ± 0.5	H ± 0.5	P ± 0.5	d_1 ± 0.1	d_2 ± 0.1	ℓ_1 MIN.	Weight g (oz)
FYL0H103Z	0.01	5.5	300	0.015	4.2	11.0 (0.43)	5.0 (0.197)	5.08 (0.200)	0.2 (0.016)	1.2 (0.047)	2.7 (0.106)	0.9 (0.032)
FYL0H223Z	0.022	5.5	200	0.033	4.2	11.0 (0.43)	5.0 (0.197)	5.08 (0.200)	0.2 (0.016)	1.2 (0.047)	2.7 (0.106)	1.0 (0.035)
FYL0H473Z	0.047	5.5	200	0.071	4.2	12.0 (0.47)	5.0 (0.197)	5.08 (0.200)	0.2 (0.016)	1.2 (0.047)	2.2 (0.087)	1.2 (0.042)

Note 1) Capacitance tolerance: +80 %, −20 %; 2) Weight is typical. 3) SD: voltage holding characteristic.

3.6 3.5 V, 6.5 V Series

Catalog NBR	Cap.	MAX. Rated Voltage	MAX. ESR	MAX. Ia	Dimensions mm (inch)						Weight
	(Farad)	(V. DC)	(Ω at 1 kHz)	(mA)	D ± 0.5	H MAX.	P ± 0.5	d_1 ± 0.1	d_2 ± 0.1	ℓ_1 MIN.	g (OZ)
FSH0V433Z	0.043	3.5	50	0.039	11.0 (0.413)	5.2 (0.205)	5.08 (0.2)	0.2 (0.008)	1.2 (0.047)	2.7 (0.106)	1.0 (0.035)
FYD0V563Z	0.056	3.5	150	0.050	11.0 (0.413)	5.2 (0.205)	5.08 (0.2)	0.2 (0.008)	1.2 (0.047)	2.7 (0.106)	1.0 (0.035)
FSH0J223Z	0.022	6.5	60	0.040	11.5 (0.453)	8.5 (0.355)	5.08 (0.2)	0.4 (0.016)	1.2 (0.047)	2.7 (0.106)	1.7 (0.060)
FYD0J273Z	0.027	6.5	200	0.049	11.5 (0.453)	8.5 (0.355)	5.08 (0.2)	0.4 (0.016)	1.2 (0.047)	2.7 (0.106)	1.6 (0.056)

Note 1) Capacitance: +80 %, −20 %; 2) Weight is typical.

3.7 FM Series (Molded type)

Catalog NBR	Cap.	MAX. Rated Voltage	MAX. ESR	MAX. Ia	MIN. SD	Dimensions mm (inch)							Weight
	(Farad)	(V. DC)	(Ω at 1 kHz)	(mA)	(V)	W ± 0.5	H ± 0.5	T ± 0.5	P ± 0.3	L ± 1.0	d_1 ± 0.1	d_2 ± 0.1	g (OZ)
FM0H103Z	0.01	5.5	300	0.015	4.2	10.5 (0.413)	11.5 (0.453)	5.0 (0.197)	5.0 (0.197)	5.0 (0.197)	0.5 (0.020)	0.4 (0.016)	1.3 (0.046)
FM0H223Z	0.022	5.5	200	0.033	4.2	10.5 (0.413)	11.5 (0.453)	5.0 (0.197)	5.0 (0.197)	5.0 (0.197)	0.5 (0.020)	0.4 (0.016)	1.3 (0.046)
FM0H473Z	0.047	5.5	200	0.071	4.2	10.5 (0.413)	11.5 (0.453)	5.0 (0.197)	5.0 (0.197)	5.0 (0.197)	0.5 (0.020)	0.4 (0.016)	1.3 (0.046)
FM0H104Z	0.1	5.5	100	0.15	4.2	10.5 (0.413)	11.5 (0.453)	6.5 (0.256)	5.0 (0.197)	5.0 (0.197)	0.5 (0.020)	0.4 (0.016)	1.6 (0.056)

Note 1) Capacitance: +80 %, −20 %; 2) Weight is typical; 3) SD: Voltage holding characteristic.

4. TECHNICAL DATA

4.1 Specification

Item		FA	FE	FS
Operating Temperature Range		−25 °C ~ +70 °C	−40 °C ~ +70 °C	−25 °C ~ +70 °C
Rated Voltage		5.5 V, 11 V	5.5 V	5.5 V
Capacitance Range		5.5 V: 0.047 F ~ 1 F 11 V: 0.022 F ~ 0.47 F	0.047 F ~ 1.5 F	0.022 F ~ 1.0 F
Capacitance Tolerance		+80 %, −20 %	+80 %, −20 %	+80 %, −20 %
ESR		See table in 3.1	See table in 3.1	See table in 3.1
Current at 30 min		See table in 3.1	See table in 3.1	See table in 3.1
Surge Voltage Test	Capacitance	—	more than 90 % of the initial requirement	more than 90 % of the initial requirement
	ESR	—	less than 120 % of the initial requirement	less than 120 % of the initial requirement
	Current	—	less than 120 % of the initial requirement	less than 120 % of the initial requirement
Temperature Characteristics Test	Capacitance	−25 °C: more than 70 % of the initial value	−40 °C: more than 40 % of the initial value	−25 °C: more than 50 % of the initial value
	ESR	less than 300 % of the initial value	less than 400 % of the initial value	less than 300 % of the initial value
	Capacitance	—	—	—
	ESR			
	Capacitance	+70 °C: less than 150 % of the initial value	+70 °C: less than 200 % of the initial value	+70 °C: less than 150 % of the initial value
	ESR	Shall meet the initial requirement.	Shall meet the initial requirement.	Shall meet the initial requirement.
	Current	Less than 1.5 CV (mA)	Less than 1.5 CV (mA)	Less than 1.5 CV (mA)
	Capacitance	+25 °C: within ±20 % of the initial value	+25 °C: within ±20 % of the initial value	+25 °C: within ±20 % of the initial value
	ESR	Shall meet the initial requirement.	Shall meet the initial requirement.	Shall meet the initial requirement.
	Current	Shall meet the initial requirement.	Shall meet the initial requirement.	Shall meet the initial requirement.
Vibration Test	Capacitance ESR Current	Shall meet the initial requirement.	Shall meet the initial requirement.	Shall meet the initial requirement.
Solderability		At least 75 % covered by continuous new solder coating.	At least 75 % covered by continuous new solder coating.	At least 75 % covered by continuous new solder coating.
Soldering Heat Resistance	Capacitance ESR Current	Shall meet the initial requirement.	Shall meet the initial requirement.	Shall meet the initial requirement.
Temperature Cycling	Capacitance ESR Current	Shall meet the initial requirement.	Shall meet the initial requirement.	Shall meet the initial requirement.
Moisture Resistance	Capacitance	more than 90 % of the initial value	within ±20 % of the initial value	more than 90 % of the initial requirement
	ESR	less than 120 % of the initial requirement	less than 120 % of the initial requirement	less than 120 % of the initial requirement
	Current	less than 120 % of the initial requirement	less than 120 % of the initial requirement	less than 120 % of the initial requirement
Load Life	Capacitance	more than 85 % of the initial requirement	within ±30 % of the initial value	more than 85 % of the initial requirement
	ESR	less than 120 % of the initial requirement	less than 300 % of the initial requirement	less than 200 % of the initial requirement
	Current	less than 200 % of the initial requirement	less than 200 % of the initial requirement	less than 200 % of the initial requirement
Voltage Holding Characteristics		—	—	—

FY (FYD, FYH, FYL), FM		FR		3.5 V and 6.5 V series		Test Conditions
−25 °C ~ +70 °C		−40 °C ~ +85 °C		−25 °C ~ +70 °C		
5.5 V		5.5 V		3.5 V: 0.043 F, 0.056 F	6.5 V: 0.022 F, 0.027 F	
FYD: 0.022 F ~ 2.2 F FYH: 0.022 F ~ 1.0 F FYL: 0.01 F ~ 0.047 F FMM: 0.01 F ~ 0.1 F		0.022 F ~ 1.0 F		0.043 F	0.056 F	0.022 F	0.027 F	Refer to Measuring Method (P.12)
+80 %, −20 %		+80 %, −20 %		+80 %, −20 %		Refer to Measuring Method (P.12)
See table in 3.1		See table in 3.1		See table in 3.1		
See table in 3.1		See table in 3.1		See table in 3.1		
more than 90 % of the initial requirement		more than 90 % of the initial requirement		more than 90 % of the initial requirement		Surge Voltage: 6.3 V, Temperature: 70 ± 2 °C (FR Series 85 ± 2 °C) 1000 cycles Charge: 30 sec. Discharge: 9 min 30 sec.
less than 120 % of the initial requirement		less than 120 % of the initial requirement		less than 120 % of the initial requirement		
less than 120 % of the initial requirement		less than 120 % of the initial requirement		less than 120 % of the initial requirement		
−25 °C	more than 50 % of the initial value	−25 °C	more than 50 % of the initial value	−25 °C	more than 50 % of the initial value	
	less than 400 % of the initial value		less than 400 % of the initial value		less than 400 % of the initial value	
	—	−40 °C	more than 30 % of the initial value		—	
			less than 700 % of the initial value			
+70 °C	less than 200 % of the initial value	+85 °C	less than 200 % of the initial value	+70 °C	less than 200 % of the initial value	
	Shall meet the initial requirement.		Shall meet the initial requirement.		Shall meet the initial requirement.	
	Less than 1.5 CV (mA)		Less than 1.5 CV (mA)		Less than 1.5 CV (mA)	
+25 °C	within ±20 % of the initial value	+25 °C	within ±20 % of the initial value	+25 °C	within ±20 % of the initial value	
	Shall meet the initial requirement.		Shall meet the initial requirement.		Shall meet the initial requirement.	
	Shall meet the initial requirement.		Shall meet the initial requirement.		Shall meet the initial requirement.	
Shall meet the initial requirement		Shall meet the initial requirement.		Shall meet the initial requirement.		Frequency: 10 ~ 55 Hz/min. Time: 2 hours each for 3 directions (total 6 hours)
At least 75 % covered by continuous new solder coating		At least 75 % covered by continuous new solder coating		At least 75 % covered by continuous new solder coating		Temperature: 230 ± 5 °C Time: 5 ± 0.5 sec immersing the 1.6 mm (FA series: 2.5 mm) of lead terminal.
Shall meet the initial requirement.		Shall meet the initial requirement.		Shall meet the initial requirement.		Temperature: 260 ± 10 °C Time: 10 ± 1 sec immersing the 1.6 mm (FA series: 2.5 mm) of lead terminal.
Shall meet the initial requirement.		Shall meet the initial requirement.		Shall meet the initial requirement.		Temperature: −25 °C (FR·FE: −40 °C) +70 °C (FR: +85 °C) 5 cycles
within ±20 % of the initial value		within ±20 % of the initial value		within ±20 % of the initial value		Temperature: 40 ± 2 °C Relative Humidity: 90 ~ 95 % Time: 240 hours
less than 120 % of the initial requirement		less than 120 % of the initial requirement		less than 200 % of the initial requirement		
less than 120 % of the initial requirement		less than 120 % of the initial requirement		less than 120 % of the initial requirement		
within ±30 % of the initial value		within ±30 % of the initial value		within ±30 % of the initial value		Temperature: 70 ± 2 °C (FR: 85 °C ± 2 °C) Applied Voltage: Rated Voltage Series Resistance: 0 Ω Time: 1000 hours
less than 200 % of the initial requirement		less than 200 % of the initial requirement		less than 300 % of the initial requirement		
less than 200 % of the initial requirement		less than 200 % of the initial requirement		less than 200 % of the initial requirement		
Voltage between terminal leads shall be higher than 4.2 V.		Voltage between terminal leads shall be higher than 4.2 V.		Voltage between terminal leads shall be higher than 4.2 V.		Charge: Applied Voltage: 5 V, Time: 24 hours Discharge: Time: 24 hours

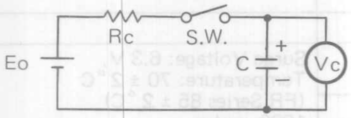
4.2 Measuring Method

(1) Capacitance

Capacitance can be calculated using the formula in **Fig. 1** by using the charging time constant (τ) being measured from the circuit diagram.

$$C = \frac{\tau}{Rc} \ (F)$$

Eo : 3.0 V. DC for Rated Voltage Code 0V (3.5 V)
: 5.0 V. DC for Rated Voltage Code 0H (5.5 V)
: 6.0 V. DC for Rated Voltage Code 0J (6.5 V)
: 10.0 V. DC for Rated Voltage Code 1A (11 V)



τ : Time period (sec) to reach $V_c = 0.632$ Eo

Rc :

Cap \ Series	FA	FE	FS	FY: FYD	FY: FYH	FY: FYL	FM	FR	3.5 V, 6.5 V
0.01F	—	—	—	—	—	5 kΩ	5 kΩ	—	
0.022F	1 kΩ	—	1 kΩ	2 kΩ	2 kΩ	2 kΩ	2 kΩ	2 kΩ	0.022 F ~ 0.056 F 2 kΩ
0.047F	1 kΩ	1 kΩ	1 kΩ	2 kΩ	1 kΩ	2 kΩ	2 kΩ	1 kΩ	
0.1F	510 Ω	510 Ω	510 Ω	1 kΩ	510 Ω	—	1 kΩ	1 kΩ	—
0.22F	200 Ω	200 Ω	200 Ω	510 Ω	510 Ω	—	—	510 Ω	—
0.47F	100 Ω	100 Ω	100 Ω	200 Ω	200 Ω	—	—	200 Ω	—
1.0F	51 Ω	51 Ω	100 Ω	100 Ω	100 Ω	—	—	100 Ω	—
1.4F	—	—	—	200 Ω	—	—	—	—	—
1.5F	—	51 Ω	—	—	—	—	—	—	—
2.2F	—	—	—	100 Ω	—	—	—	—	—

Fig. 1 Capacitance Measurement

(2) Equivalent series resistance (ESR)

A measuring circuit and formula are shown in **Fig. 2.**

$$ESR = \frac{Vc}{10^{-2}} \ (\Omega)$$

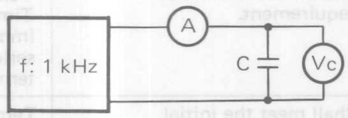


Fig. 2 ESR Measurement

(3) Current (at 30 minutes after charging)

A measuring circuit and formula are shown in **Fig. 3.**

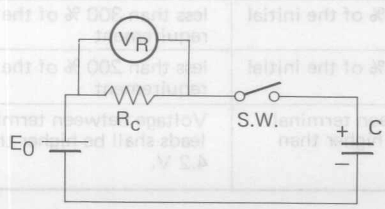
Current shall be calculated from the equation below.

Prior to measurement, both lead terminals must be short-circuited for a minimum of 30 minutes.

The lead terminal connected to the metal can case is connected to the negative side of the power supply.

E_0 : The same as 4.2 (1) above

R_c : 0.01F to 0.056F 1,000 Ω
0.10 to 0.47F 100 Ω
1.0F to 2.2F 10 Ω



$$\text{Current} = \frac{V_R}{R_c} \times 10^3 \ (\text{mA})$$

Fig. 3 Current Measurement

4.3 Charge/Discharge Characteristics

(1) Charging characteristics

Charging characteristics of 5 V, 0.047F is shown in **Fig. 4.**

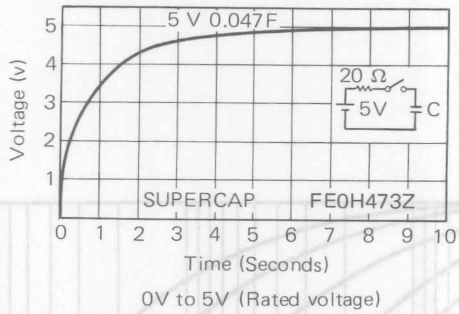


Fig. 4 Charging Characteristics

SUPERCAP, as a battery, has excellent charging characteristics since it can be charged within seconds.

(2) Charging Current

Fig. 5 shows a typical charging current, which reaches very low current level (i.e. leakage current) long hours after the charging started.

The power dissipation in keeping the rated voltage applied to the **SUPERCAP** can be roughly estimated by this ultimate leakage current.

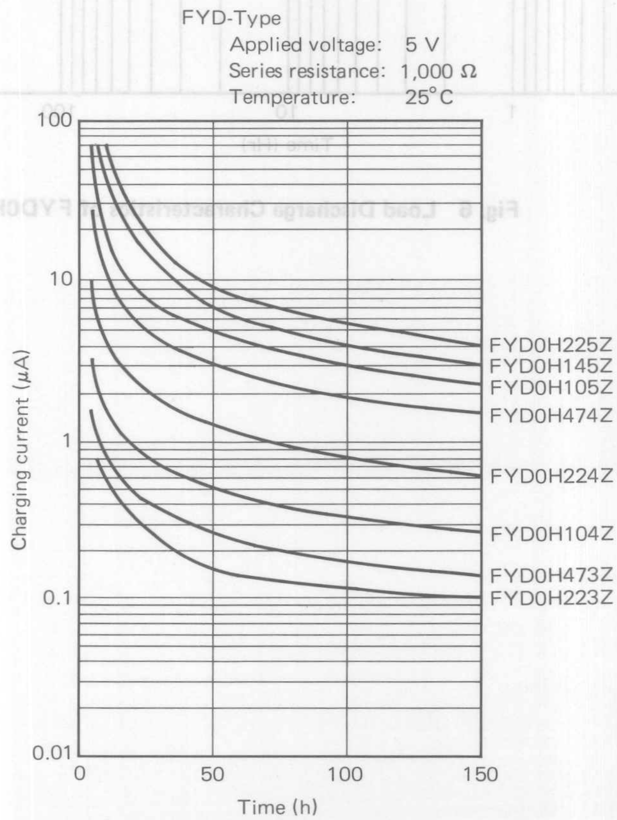


Fig. 5 Charging Current

(3) Discharge Characteristics

Only a figure for discharge characteristics of FYD0H473Z is mentioned typically here in this section, however many figures for all the types are necessary and very useful for the capacitance selection in circuit design.

All of those figures are mentioned in later section of Capacitance Selection Method.

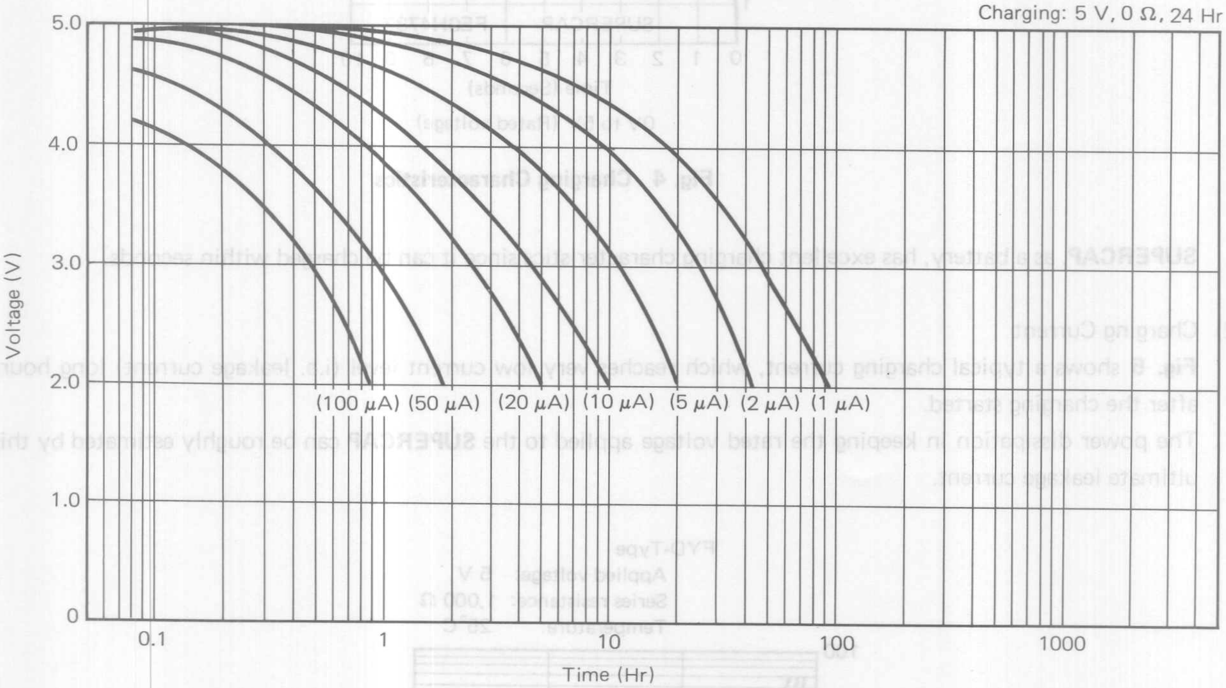


Fig. 6 Load Discharge Characteristics of FYD0H473Z

(4) Self discharge characteristics

Self discharge characteristics shown in **Fig. 7.**

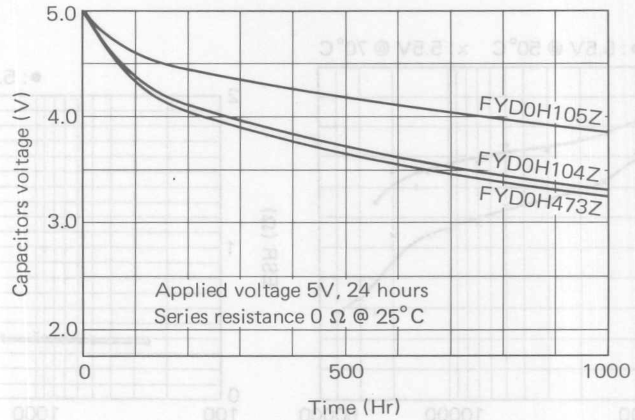


Fig. 7 Voltage Holding Characteristics of FYD Series

4.4 Life Test Data

The following information is reference data and not guaranteed specifications.

(1) Charge/discharge cycles

Fig. 8 shows capacitance and ESR change during 15,000 charge/discharge cycle life test.

The time period is 30 sec on charge and 30 sec on discharge with no series resistors connected.

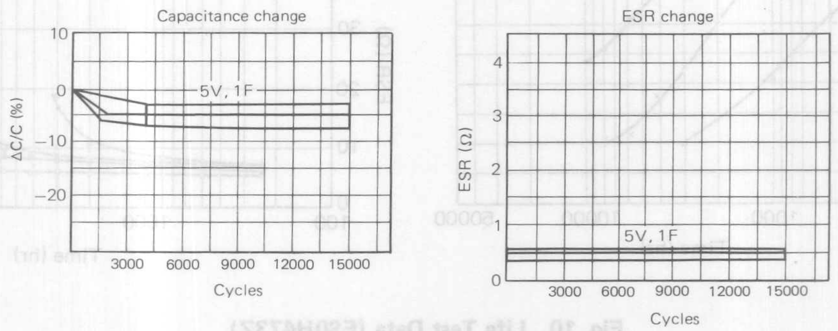


Fig. 8 Charge/Discharge Cycle Test Data

The test conditions are more severe than NEC guarantee specification.

Charging and discharging **SUPERCAP** is limitless in repetition because the mechanism is based on physical phenomena which gives no damage to **SUPERCAP** at all.

While since a Ni-Cd battery makes use of a chemical reaction, it can not be repeated more than a few hundred cycles.

(2) Life test at maximum operating temperature

Capacitance and ESR change at life test, are typically shown in **Fig. 9, Fig. 10** and **11**.

The test conditions are more severe than NEC guarantee specification.

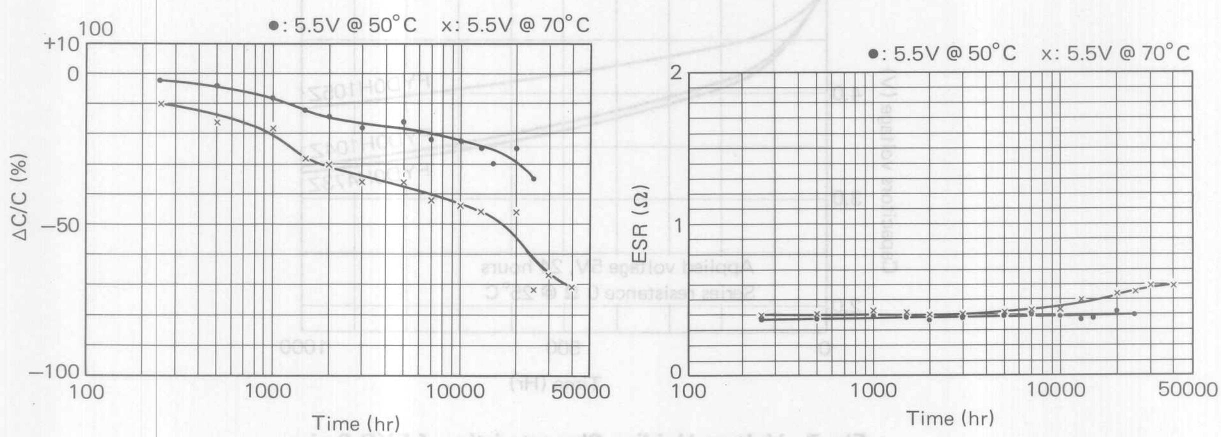


Fig. 9 Life Test Data (FA0H105Z)

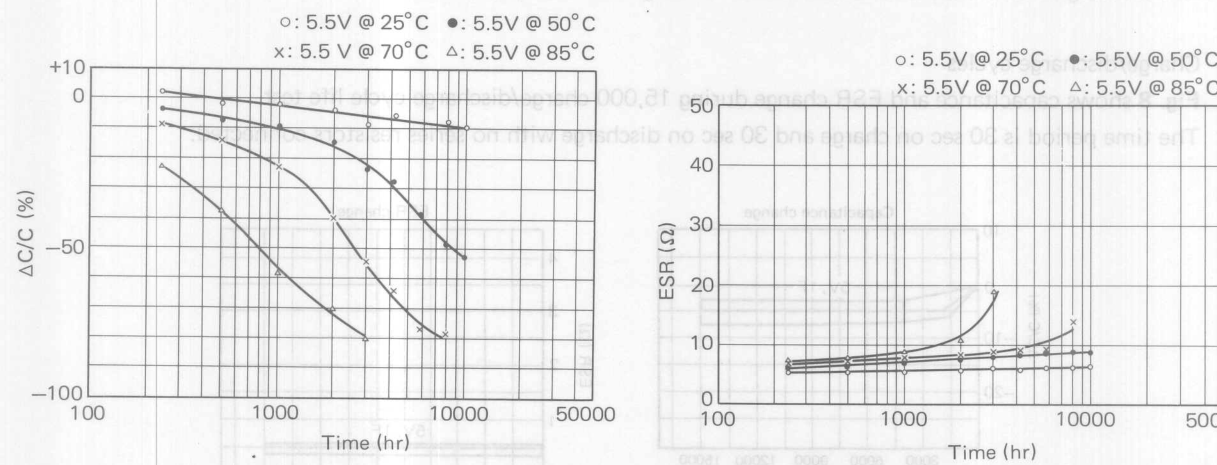


Fig. 10 Life Test Data (FS0H473Z)

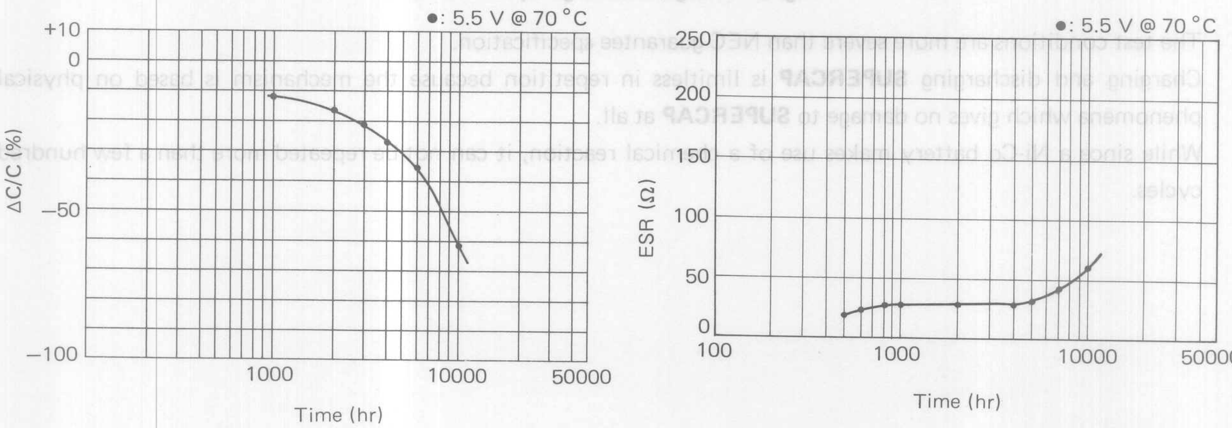


Fig. 11 Life Test Data (FYD0H474Z)

(3) Storage life at high/low temperature

Fig. 12, 13 and **Fig. 14, 15** are typical storage life test data at 85 °C for 1,000 h and –40 °C for 500 h respectively.

The test conditions are more severe than NEC guarantee specification.

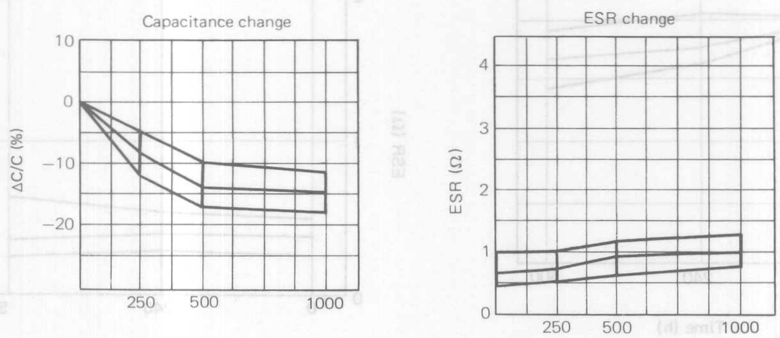


Fig. 12 Storage Life Test Data; at 85 °C (FA0H105Z)

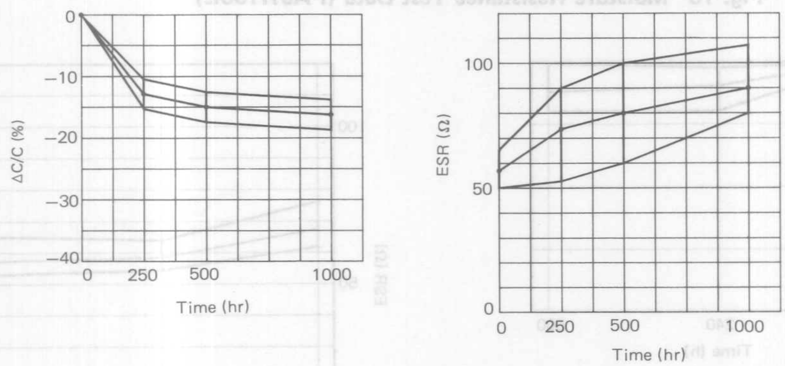


Fig. 13 Storage Life Test Data: at 85 °C (FYH0H473Z)

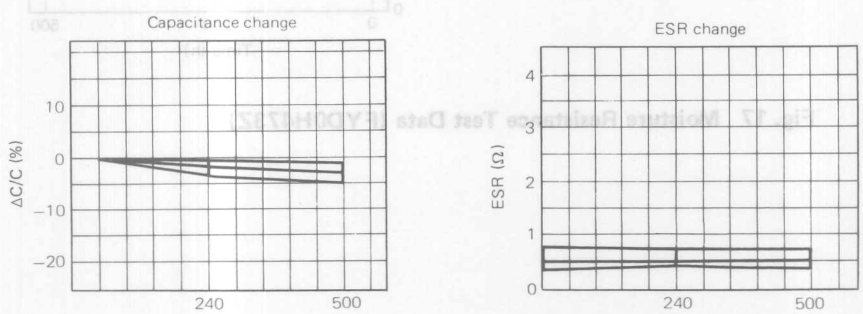


Fig. 14 Storage Life Test Data; at –40 °C (FA0H105Z)

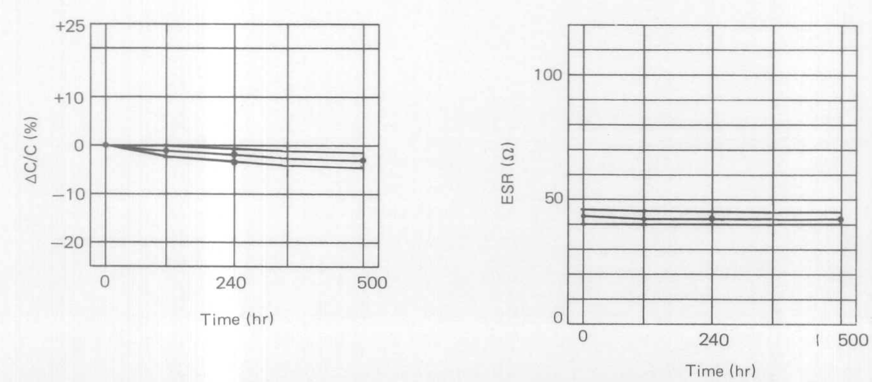


Fig. 15 Storage Life Test Data: at –40 °C (FYH04H473Z)

(4) Moisture Resistance

Fig. 16 and **Fig. 17** are Moisture Resistance test data at 40 °C, 90 to 95 % relative humidity, with no voltage applied, for 500 h.

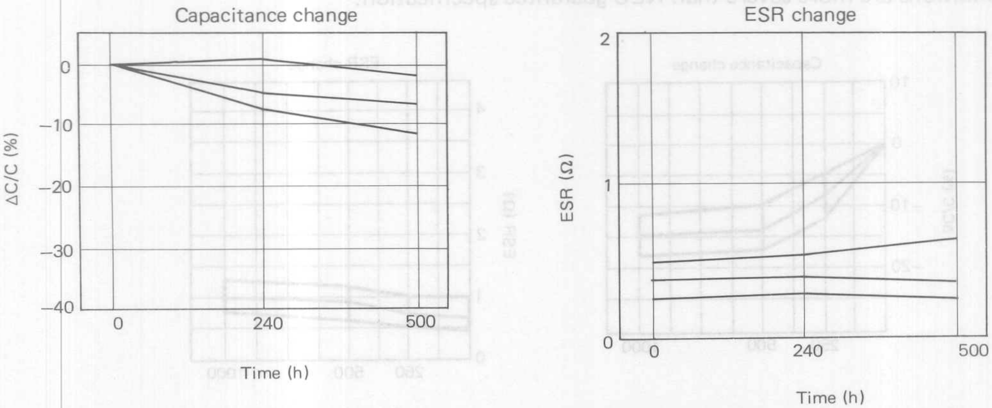


Fig. 16 Moisture Resistance Test Data (FA0H105Z)

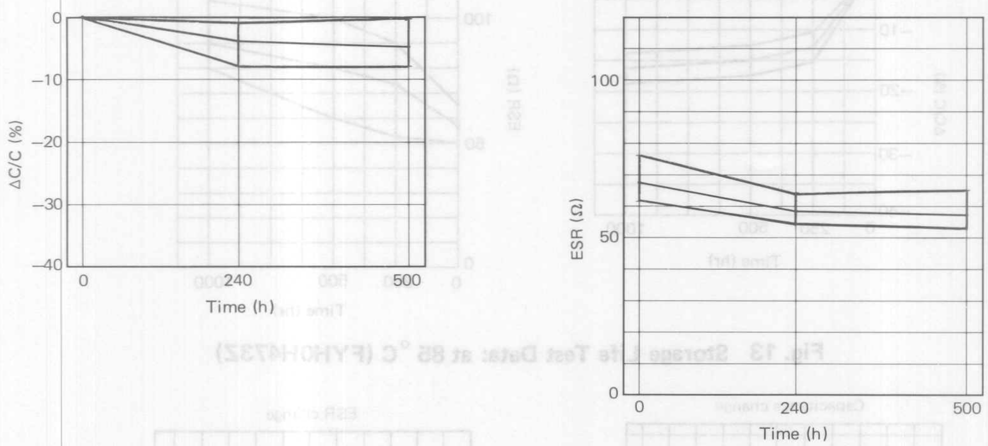


Fig. 17 Moisture Resistance Test Data (FYD0H473Z)

4.5 Environmental Test Data

The following information is reference data and not guaranteed specifications.

(1) Temperature characteristics

Fig. 18 and **Fig. 19** show typical changes with temperature in capacitance and ESR over the operating temperature range of −25 °C to +70 °C.

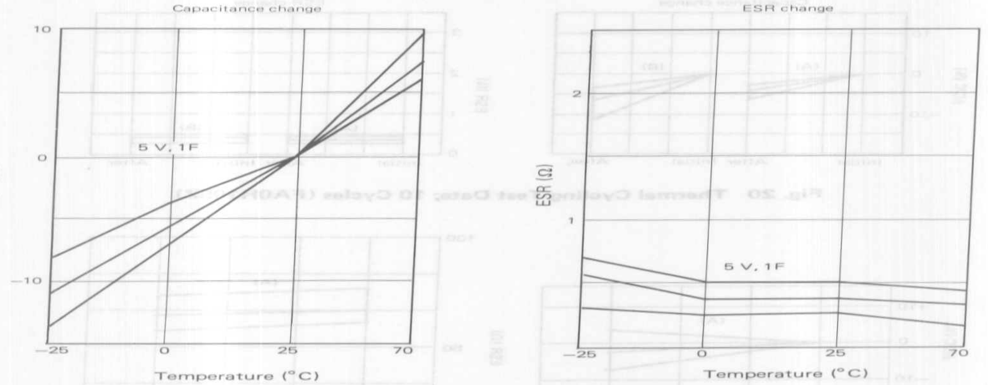


Fig. 18 Temperature Characteristics (FA0H105Z)

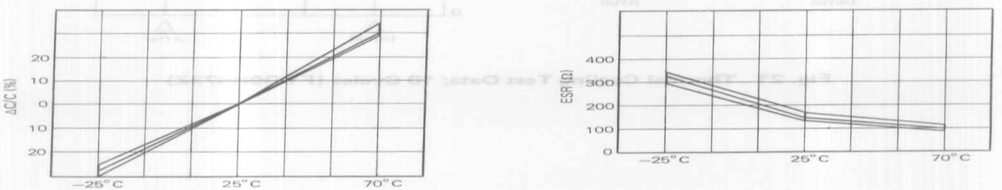


Fig. 19 Temperature characteristics (FYD0H473Z)

(2) Thermal cycling test

Capacitance and ESR of **SUPERCAP** shall be within the initial requirements after 5 thermal cycles, which consists of 30 min. each successive exposure at −25 °C, +25 °C, +70 °C and +25 °C per each cycle. **Fig. 20** and **Fig. 21** typically show more extensive test result from 10 cycles of −30 °C to +85 °C (test A) and 10 cycles of −30 °C to +100 °C (test B).

No degradation was found in these tests.

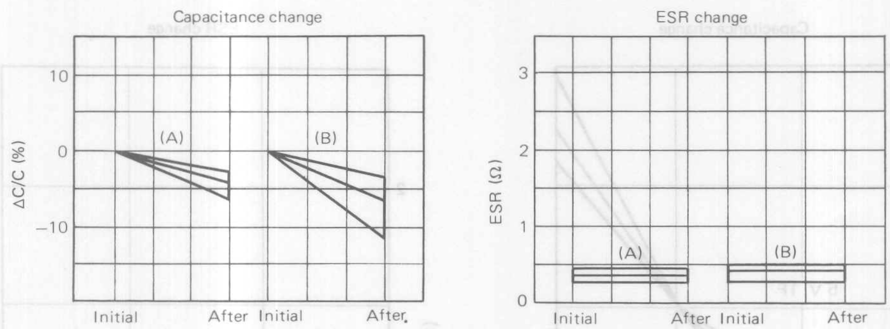


Fig. 20 Thermal Cycling Test Data; 10 Cycles (FA0H105Z)

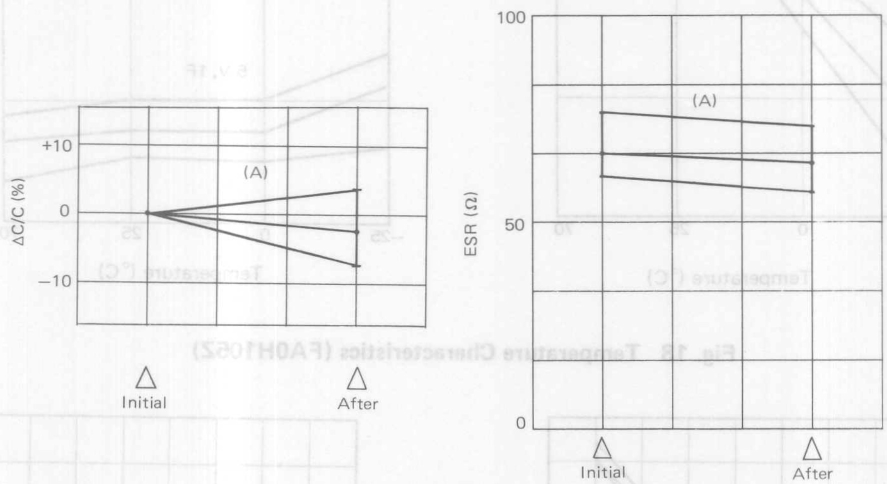


Fig. 21 Thermal Cycling Test Data; 10 Cycles (FYD0H473Z)

(3) Vibration/Mechanical shock test

Typical change in capacitance and ESR after the tests are shown in **Fig. 22, 23** and **Fig. 24.**

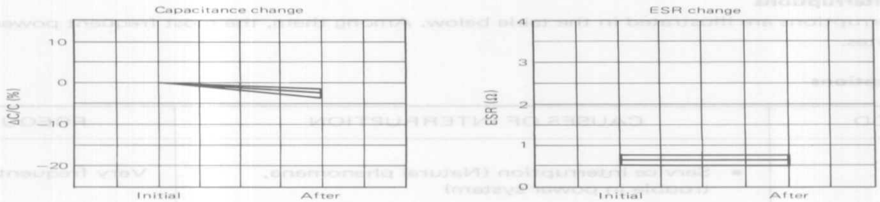


Fig. 22 Vibration Test; 10 Hz to 55 Hz, 6 Hours (FA0H105Z)

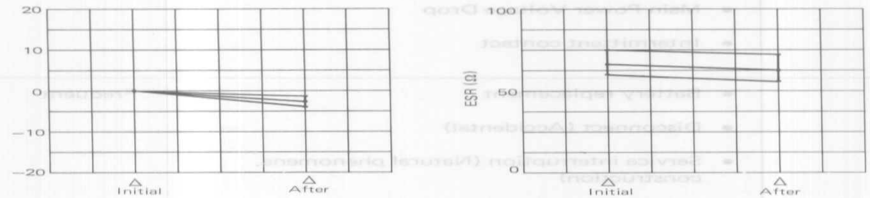


Fig. 23 Vibration Test: 10 Hz to 55 Hz, 6 Hours (FYD0H473Z)

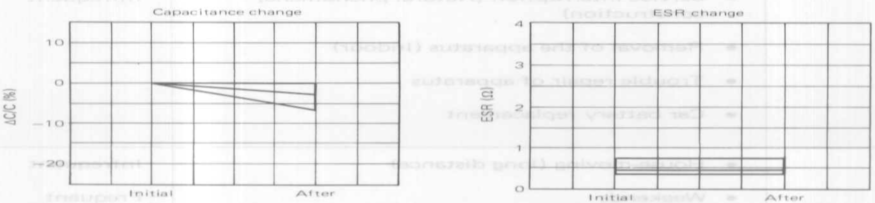


Fig. 24 Mechanical Shock Test; MIL-STD-202E, Method 205 (FA0H105Z)

5. APPLICATION NOTES

5.1 Major Power Interruptions

Major power interruptions are illustrated in the table below. Among them, the most frequent power outages range less than a few minutes.

Major Power Interruptions

TIME PERIOD	CAUSES OF INTERRUPTION	FREQUENCY
Second(s)	• Service interruption (Natural phenomena, trouble in power system) • Disconnect (Accidental) • Main Power Voltage Drop • Intermittent contact	Very frequent
Minute(s)	• Battery replacement • Disconnect (Accidental) • Service interruption (Natural phenomena, construction) • Removal of apparatus (Indoor)	Frequent
Hour(s)	• Service interruption (Natural phenomena, construction) • Removal of the apparatus (Indoor) • Trouble repair of apparatus • Car battery replacement	Infrequent
Day(s)	• House-moving (long distance) • Weekends	Infrequent Frequent
Week(s)	• Stoppage of power supply during holidays and summer vacations	1 ~ 2 times/year

5.2 Power Backup Design

Certain parameters must be considered in defining the type of energy source required for standby power. These include the following:

- Voltage level (minimum to retain memory or standby conditions)
- Current requirements (minimum to retain memory or standby conditions)
- Duration of power outages expected (or time on "Standby power")
- Shelf and operational life expected (or the needs for maintenance)
- Storage and operating range, and other environmental considerations
- Device size, reliability and safety, plus consideration to simple P.C. board assembly
- Cost (Not only device cost, but overall installation cost for related circuits, assembly, etc.)

Once these parameters are well defined, in many instances, it will become apparent that **SUPERCAP** provides a reliable, maintenance free, and cost effective standby power source.

It is suggested that **FA, FE, FS, FR, FY,** and **FM Series SUPERCAP** should be selectively used as follows: (See **Fig. 25**)

FA and FE Series: Medium to large current (50 miliampares or more) for short time backup applications.
FS Series: Small current (less than 50 miliampares) for several minutes backup applications.
FR, FY, and FM Series: Very small current (less than 500 μA) for several weeks backup applications.

This selection guideline is recommended due to the difference of max ESR specifications. (See **Fig. 26 (a), (b), 27, 28** for detailed backup time capability.)

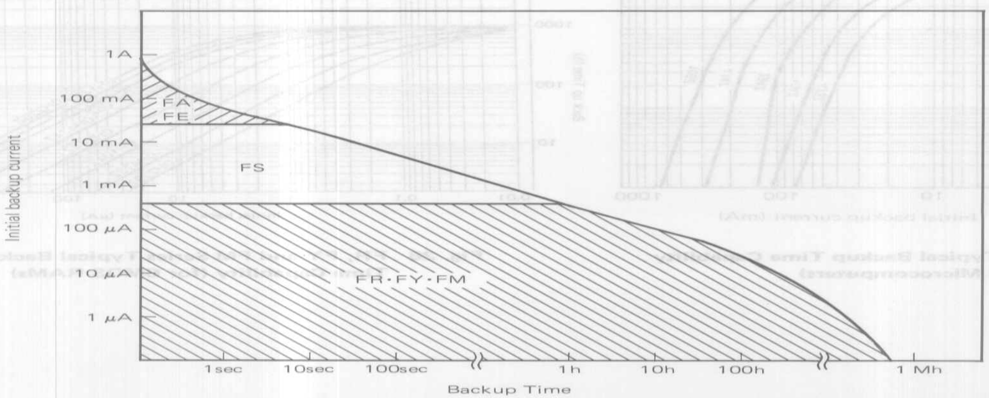


Fig. 25

5.3 Backup Time Capability

Relation between backup current and backup time period is given in **Fig. 26, Fig. 27** and **Fig. 28.**

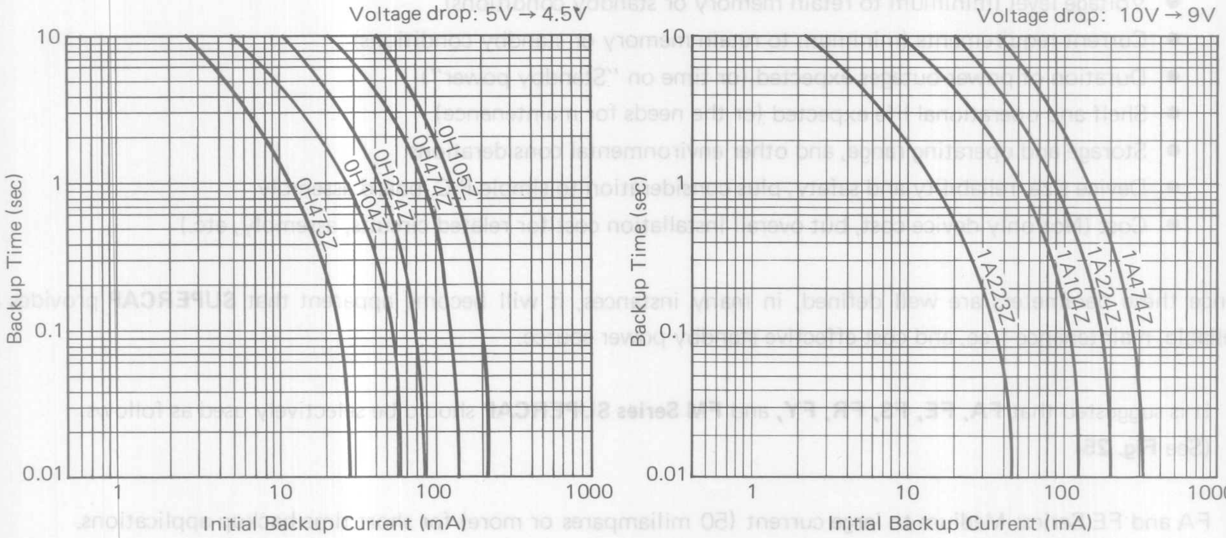


Fig. 26 (a), (b) FA and FE Series Typical Backup Time Capability (for Microcomputers)

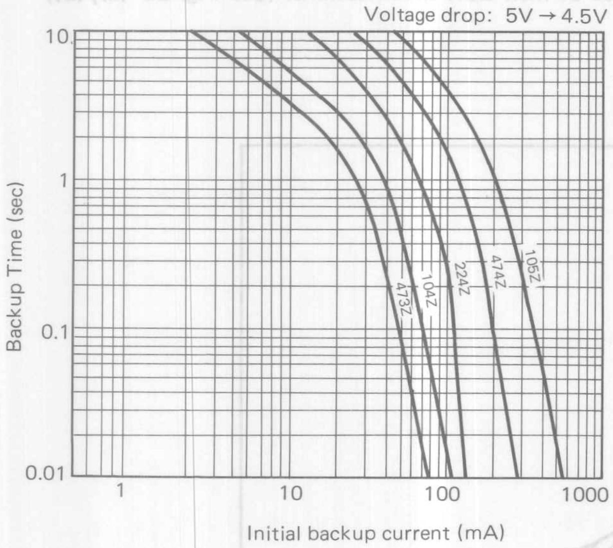


Fig. 27 FS Series Typical Backup Time Capability (for CMOS Microcomputers)

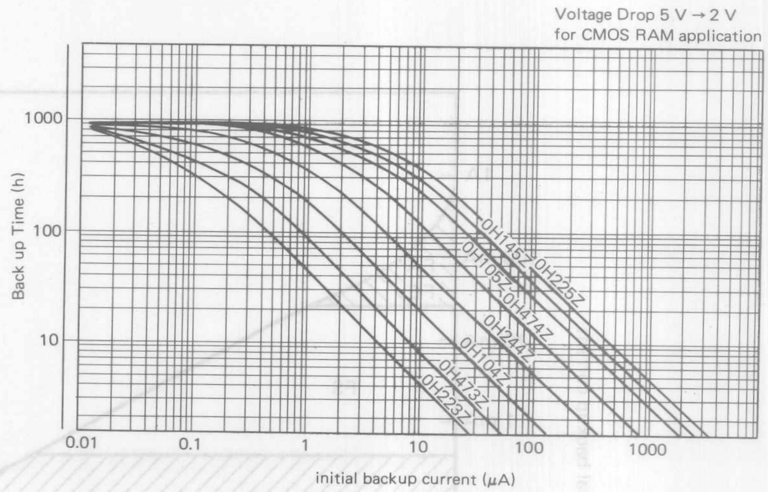
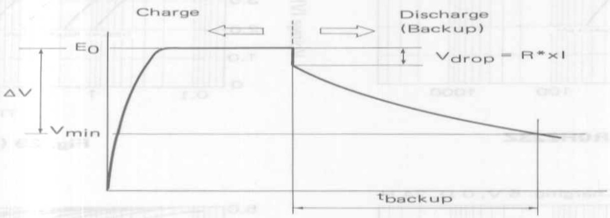


Fig. 28 FR, FY and FM Series Typical Backup Time Capability (for CMOS RAMs)

5.4 Capacitance Selection Method

(1) To obtain the capacitance for the initial backup current from several μA to several hundred μA, use **Fig. 29** to **Fig. 32** of FY, FR and FM series.
Discharge characteristics on page 25 to 28.

(2) For the backup current from several hundred to 1 A, use the following Formula (1) below to determine the capacitance.
This is applicable for FA, FE and FS series.



$$\boxed{Cap = \frac{I \times t_{backup}}{\Delta V - V_{drop}}} \quad [F] \text{ — (1)}$$

where

$\Delta V = E_O - V_{min}$

V_{min} → Min. Working Voltage for Load

ΔV → Working Voltage Range for Load

I : Backup current [A]
t_{backup} : Backup time [sec]
E_O : Charged voltage [V]
V_{drop} = $R^{*} \times I$ [V]

* The following is value for R.

Catalog NBR	R (TYP.) (Ω)
FA0H473Z	13
FA0H104Z	4
FA0H224Z	3
FA0H474Z	2
FA0H105Z	1
FA1A223Z	20
FA1A104Z	4
FA1A224Z	1.7
FA1A474Z	1.2

FE's value is equal to FA's.

Catalog NBR	R (TYP.) (Ω)
FS0H473Z	9
FS0H104Z	5
FS0H224Z	7
FS0H474Z	3.5
FS0H105Z	2

Load Discharge Characteristics for Capacitance Selection

- FR Series

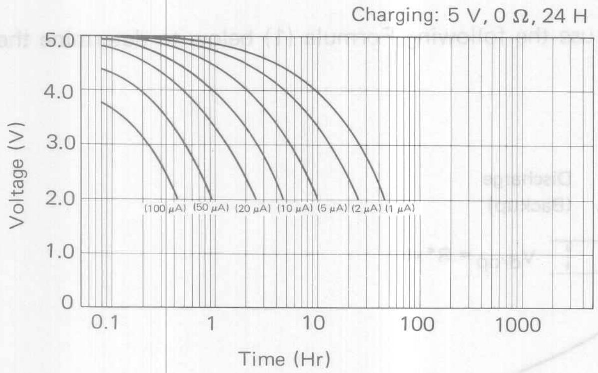


Fig. 29 (a) FR0H223Z

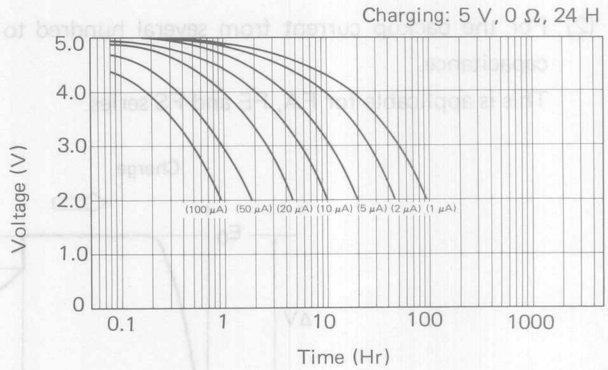


Fig. 29 (b) FR0H473Z

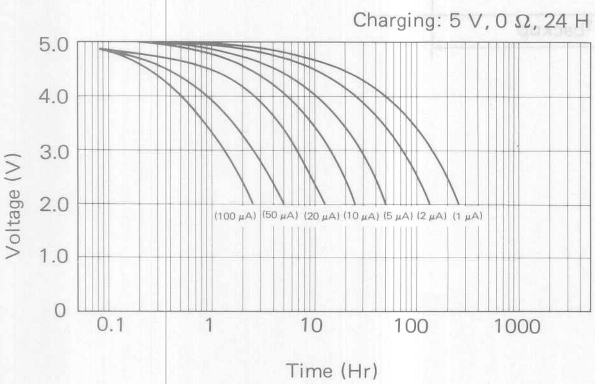


Fig. 29 (c) FR0H104Z

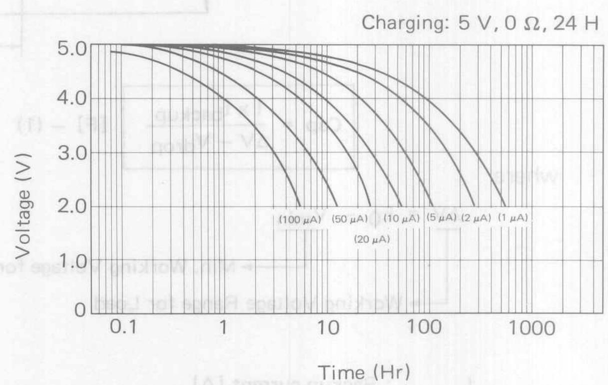


Fig. 29 (d) FR0H224Z

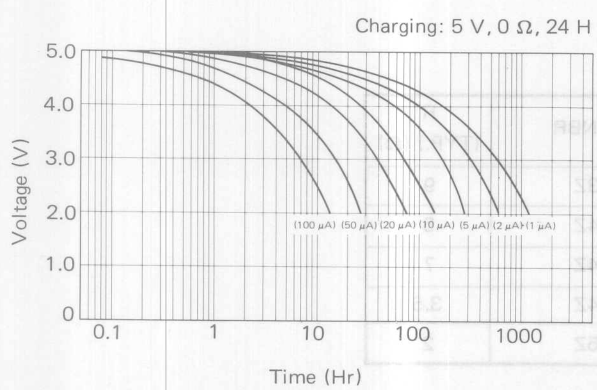


Fig. 29 (e) FR0H474Z

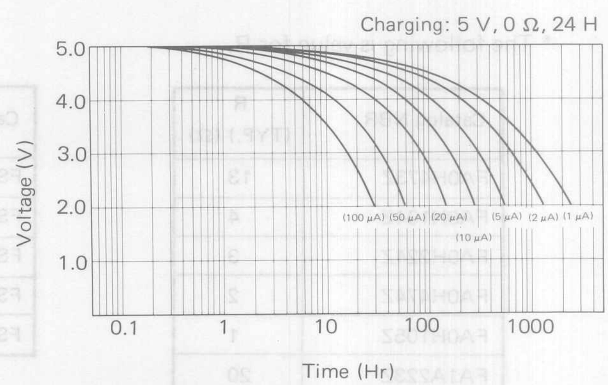


Fig. 29 (f) FR0H105Z

- FYH Series

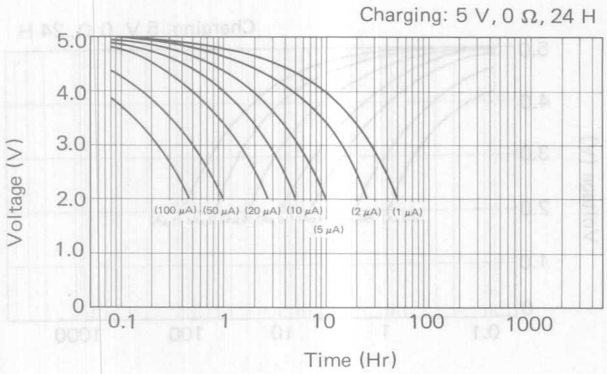


Fig. 30 (a) FYH0H223Z

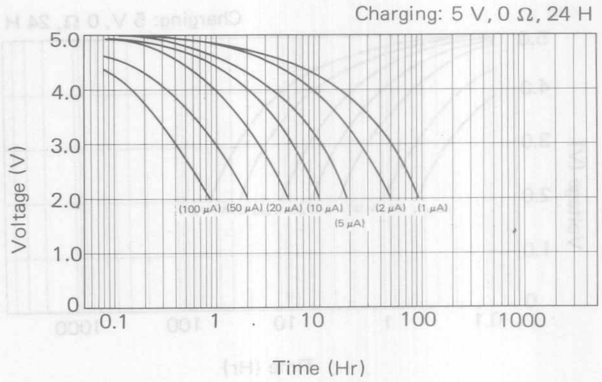


Fig. 30 (b) FYH0H473Z

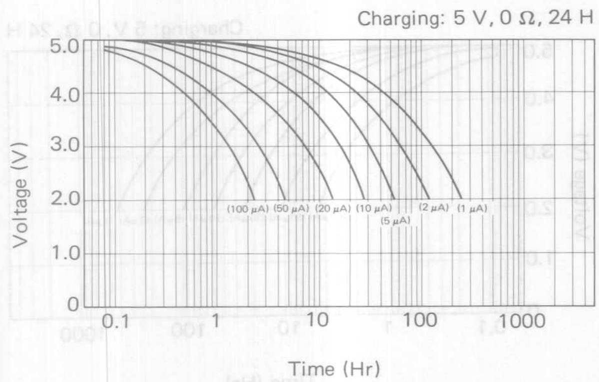


Fig. 30 (c) FYH0H104Z

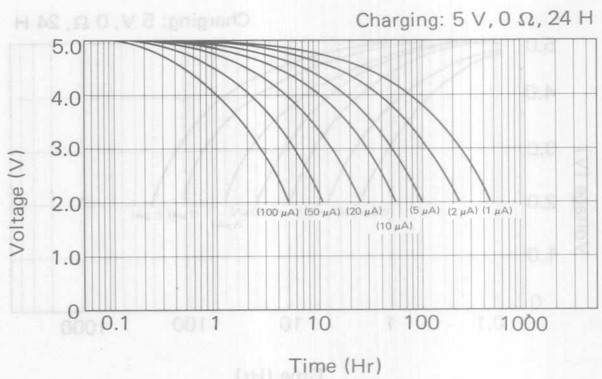


Fig. 30 (d) FYH0H224Z

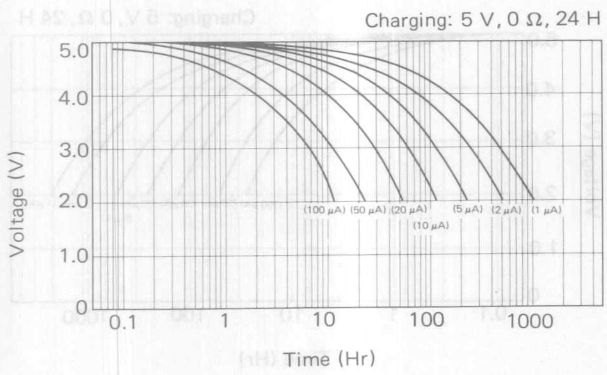


Fig. 30 (e) FYH0H474Z

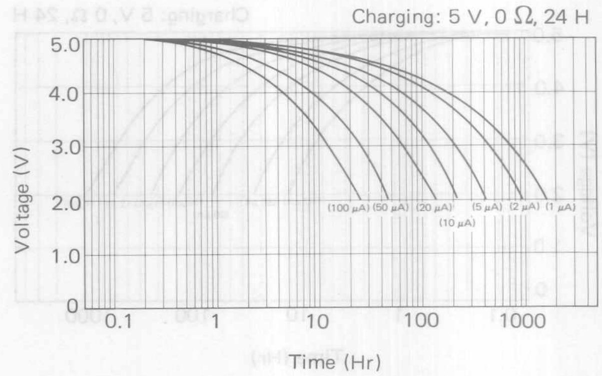


Fig. 30 (f) FYH0H105Z

● FYD Series

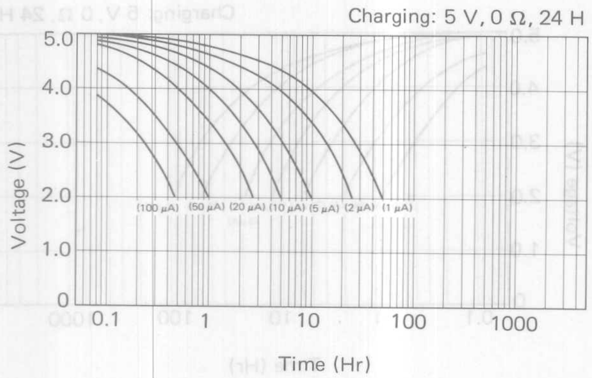


Fig. 31 (a) FYD0H223Z

Fig. 31 (b) FYD0H473Z

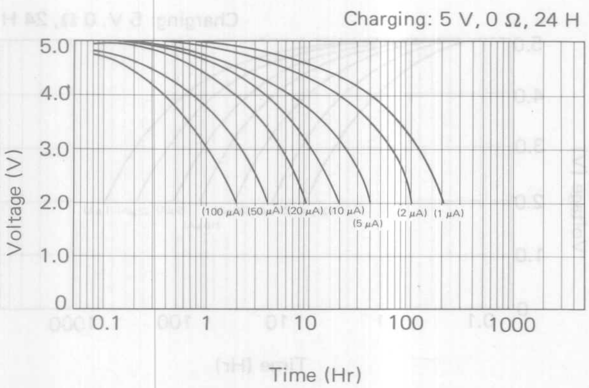


Fig. 31 (c) FYD0H105Z

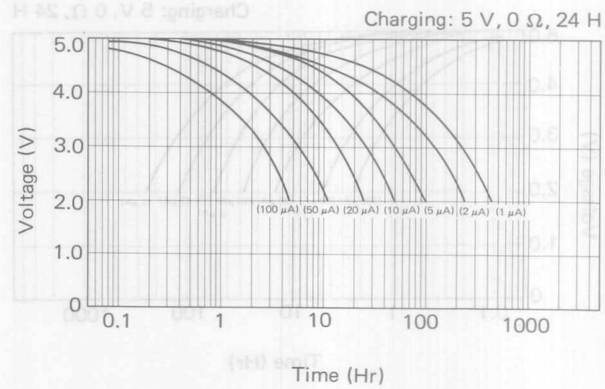


Fig. 31 (d) FYD0H224Z

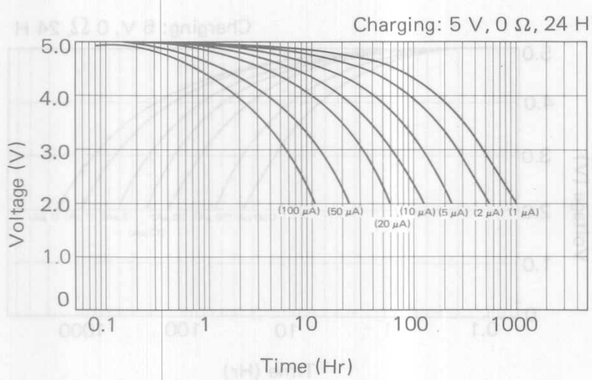


Fig. 31 (e) FYD0H474Z

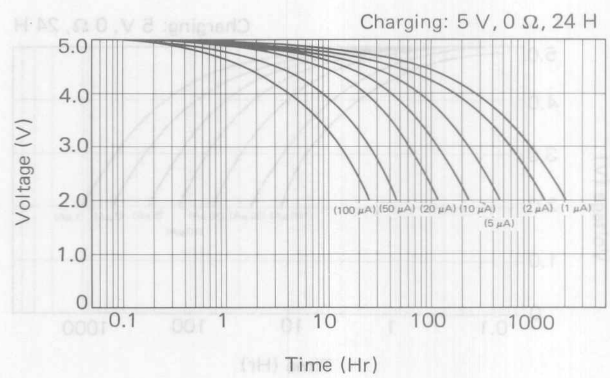


Fig. 31 (f) FYD0H105Z

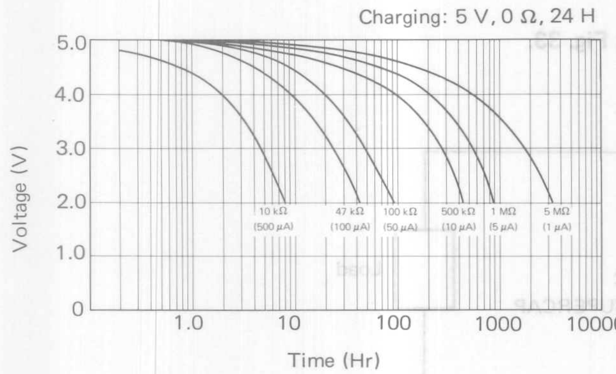


Fig. 31 (g) FYD0H225Z

- FM Series

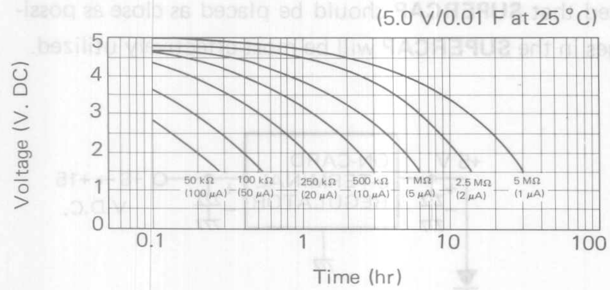


Fig. 32 (a) FM0H103Z

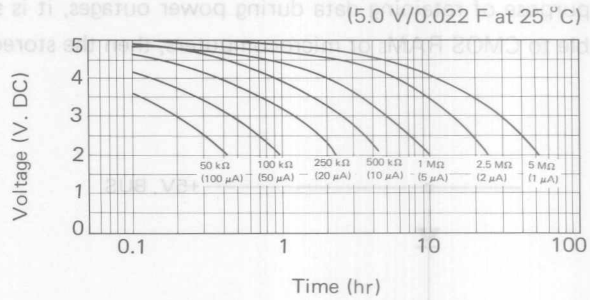


Fig. 32 (b) FM0H223Z

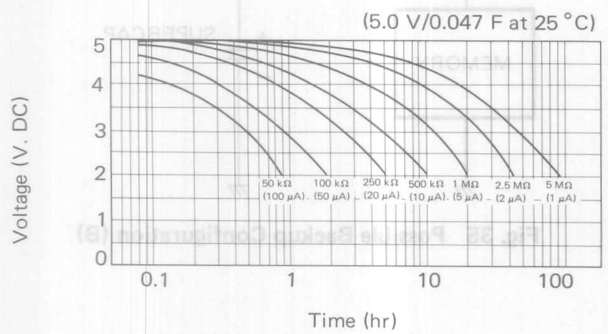


Fig. 32 (c) FM0H473Z

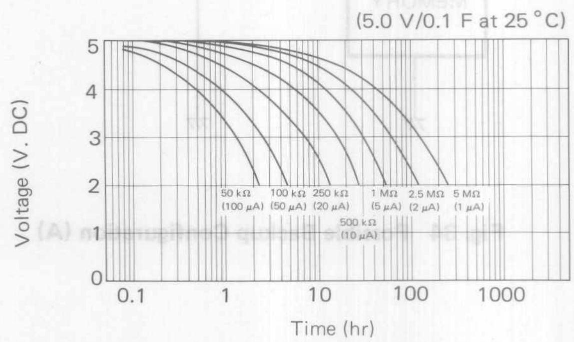


Fig. 32 (d) FM0H104Z

5.5 Backup Circuit

Basic circuit diagram in use of the **SUPERCAP** is shown in **Fig. 33.**

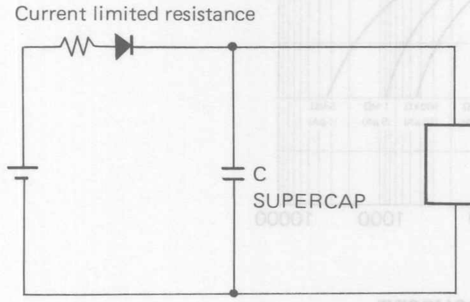


Fig. 33 SUPERCAP Basic Circuit

The diode shall be placed to isolate the primary power supply from the **SUPERCAP** during power interruption.

The backup time capability of the **SUPERCAP** depends on the current magnitude of the load circuit. For the purpose of retaining data during power outages, it is suggested that **SUPERCAP** should be placed as close as possible to CMOS RAMs or microcomputers, then the stored charges in the **SUPERCAP** will be most effectively utilized.

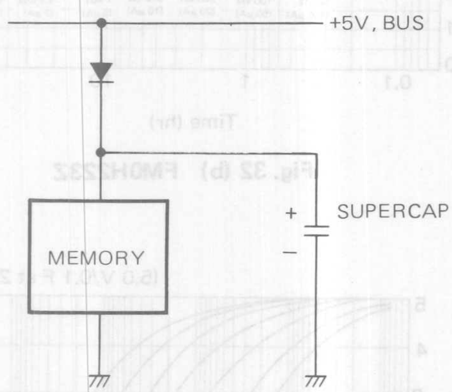


Fig. 34 Possible Backup Configuration (A)

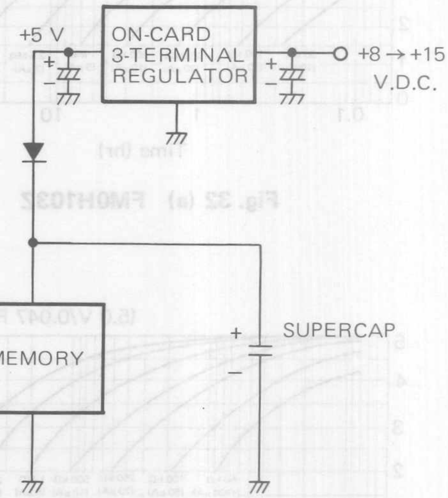


Fig. 35 Possible Backup Configuration (B)

5.5.1 Example Application of Supercap

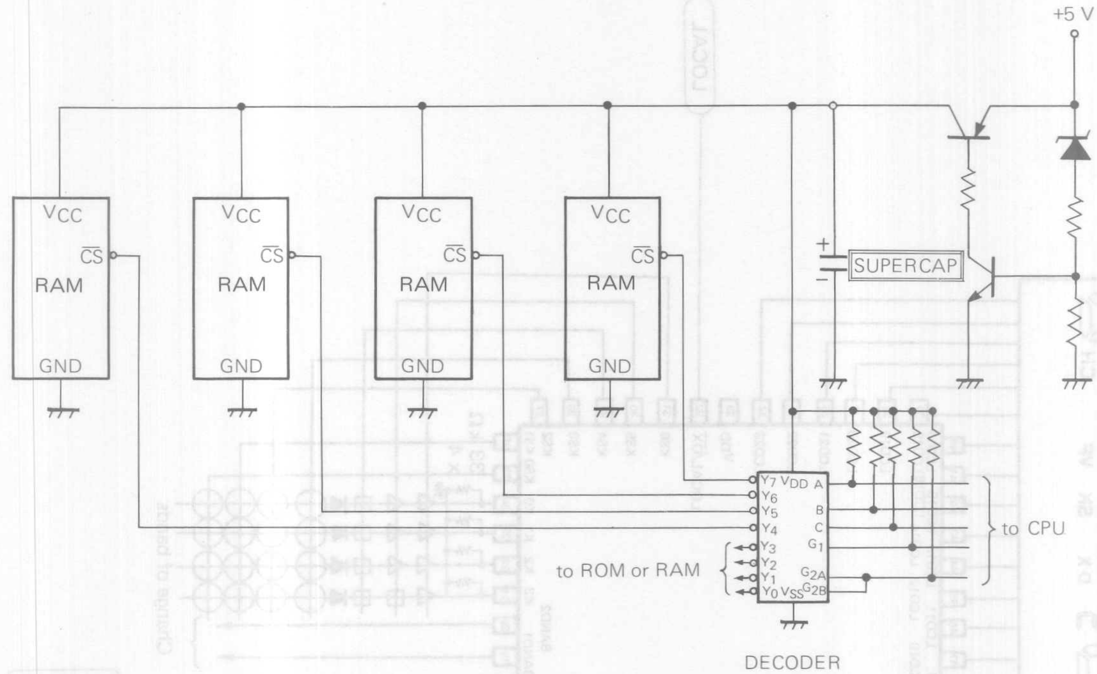


Fig. 36 Memory Backup Circuit Diagram

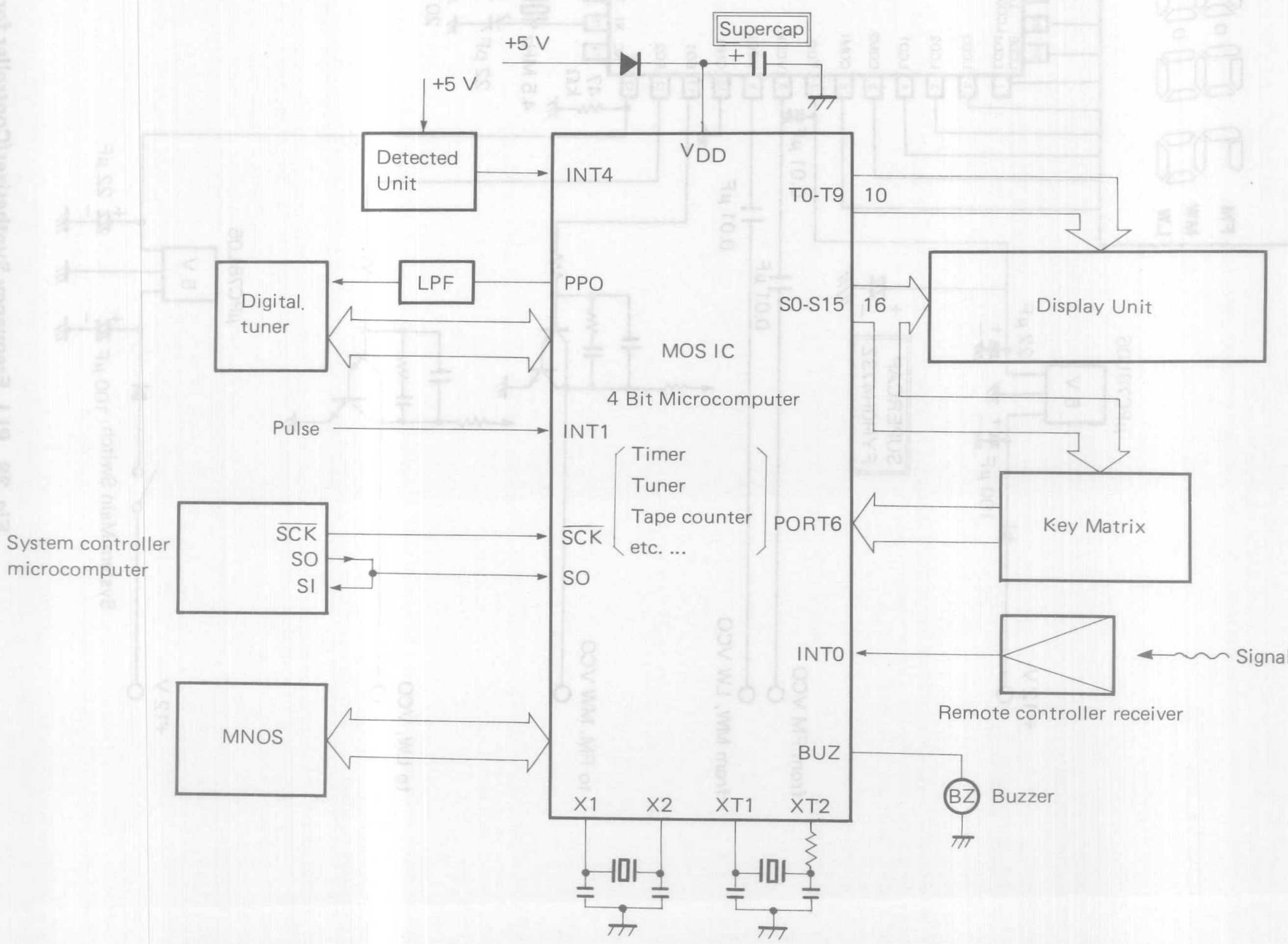


Fig. 37 VCR Microcomputer Application Circuit

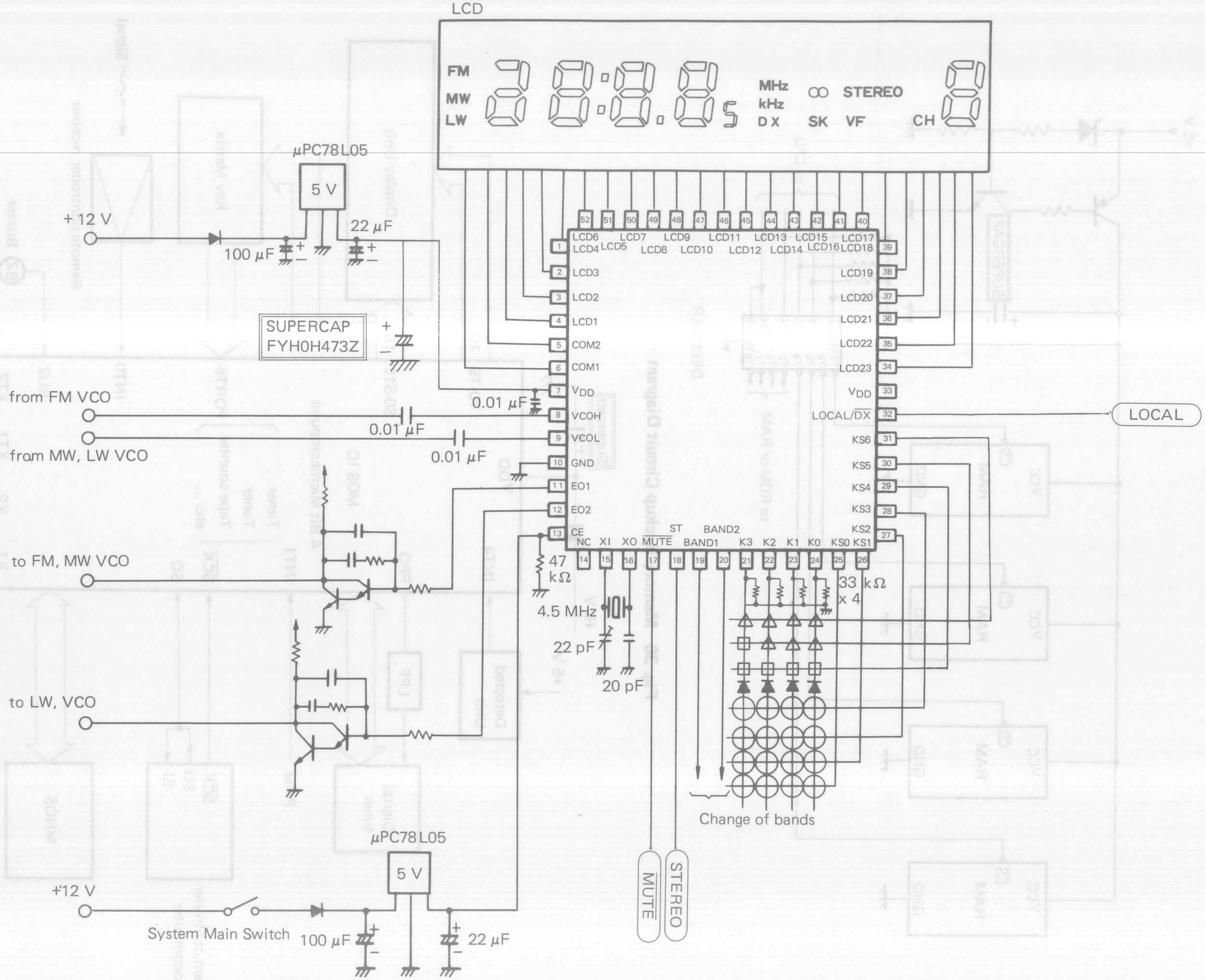


Fig. 38 PLL Frequency Synthesizer/Controller for LW, MW, FM Digital Tuner Application Circuit

5.6 Typical Applications

Typical applications categolized by the functions and the magnitude of backup current required are shown in the table below.

Typical Applications for SUPERCAP

FUNCTIONS	BACKUP CURRENT	APPLICATIONS	EQUIPMENT	ADEQUATE SERIES
Large current supply	Up to 1 A	Actuator applications (Large current in a short period)	Actuators Relay/Solenoid starter Igniters	FA and FE Series
		Primary power supply for LED displays, toys, electric buzzer etc.	Handheld toys Displays, Smoke detectors, Alarm devices, Emergency display	
Medium capacity power supply	Up to 50 mA	Secondary power source for undesirable voltage drops	Car radio back-up at the engine start, etc.	FS Series 3.5 V·6.5 V Series (FSH)
		Motor Start	VCR, Video disk Record player	
Power backup for primary power outages	Less than 500 μA	CMOS Microcomputers	Phones (Memory dial, Auto-answering) Electric cash registers Electric typewriters Computer terminals Automatic measuring instruments etc.	FY Series (FYD Type FYH Type FYL Type) 3.5 V·6.5 V Series (FYD) FM Series
		CMOS RAMs ICs for Clocks	Digital tuning audio system (LW-MW-FM Radio, Car Radio, Stereo, etc.) Programmable consumer electronic products (VCR, Microwave oven, Games, etc.)	
		• CMOS RAMs ICs for Clocks • High operating temperature (85 °C)	Measuring instruments Automatic control Communications Car	FR Series
(Other Possible Applications) Programmable thermostat, Medical Electronics, Copiers, Vending machines, Automatic Electricity Counters, Traffic signals, Taxi Meters, Fuel Management Systems, Process Monitoring or Control, Satellite Communications, Military Electronics, Avionics, Intercom, Portable "Battery" Operated Equipment, Fare collection System, POS Terminals, Mail Sorters, Scale, Flow metering, Electronic Slot Machines, Water Heat Controllers.				

Typical test results for the actual backup time capability are listed in the table below.

SUPERCAP BACKUP TIME (TYPICAL TEST RESULTS at 25 °C)

NEC ICs (Description)	Actual current	SUPERCAP tested	Backup Time (Test Results)
μPD43256AC-LL (256K bit CMOS RAM)	1.2 μA or less	FYH0H473Z	50 hours
μPD1708C (CMOS LSI for PLL Tuner)	10 μA or less (without clock)	FYH0H224Z	40 hours
μPD75216A (CMOS Microcomputer)	8 μA or less (stop mode)	FYH0H473Z	7 hours

5.7 Series/Parallel Connections

When higher rated voltage or greater capacitance (i.e., longer backup time) is required, it can be obtained by connecting **SUPERCAP** in series or in parallel respectively.

(1) Series Connection

The voltage needs to be equally distributed to the capacitors. Practically, the same production lot number capacitors shall "only" be connected in series.

Series connection of different **SUPERCAP** part numbers may cause imbalanced voltage distribution to each capacitors, resulting that excess voltage may be kept applied to a specific capacitor.

(2) Parallel Connection

No major caution is suggested. Parallel connection with different part number capacitors is allowable.

5.8 General Hints and Suggestions

(1) Due to relatively high ESR, it is not recommended to apply **SUPERCAP** in AC or filtering applications.

(2) Do not apply the voltage beyond the maximum working voltage.

(3) Do not disassemble the capacitor, as dilute sulfuric acid is moisturized to the activated carbon.

(4) Although **SUPERCAP** has no polarity, it is suggested to take the longer lead as a negative porality, since the longer lead is electrically connected to the metal can case.

(5) Grinding leads will decrease solderability.

(6) At the cleaning process after P.C board soldering, **SUPERCAP** should not be completely dipped into the solvent. Ultrasonic cleaning should also be avoided.

Solvent immersion into the **SUPERCAP** may leave undesirable solder flux residue inside the capacitors, resulting in possible ESR increase. Solvent shower or partial dipping to solvent is allowable.

6. PRINCIPLE AND STRUCTURE

6.1 Operating Principle

At every interface, an array of charged particles and induced charges is thought to exist. This array is known as an electric double layer. The large capacitance of an electric double layer capacitor arises from the charge stored at the interface by the changing electric field between two available phases. In the **SUPERCAP**, one phase is the activated carbon particle. The other phase is sulfuric acid solution, as an ionically conducting electrolyte.

The charge distribution at the interface is illustrated in **Fig. 39 (a)**, **Fig. 39 (b)** shows that with electric field applied.

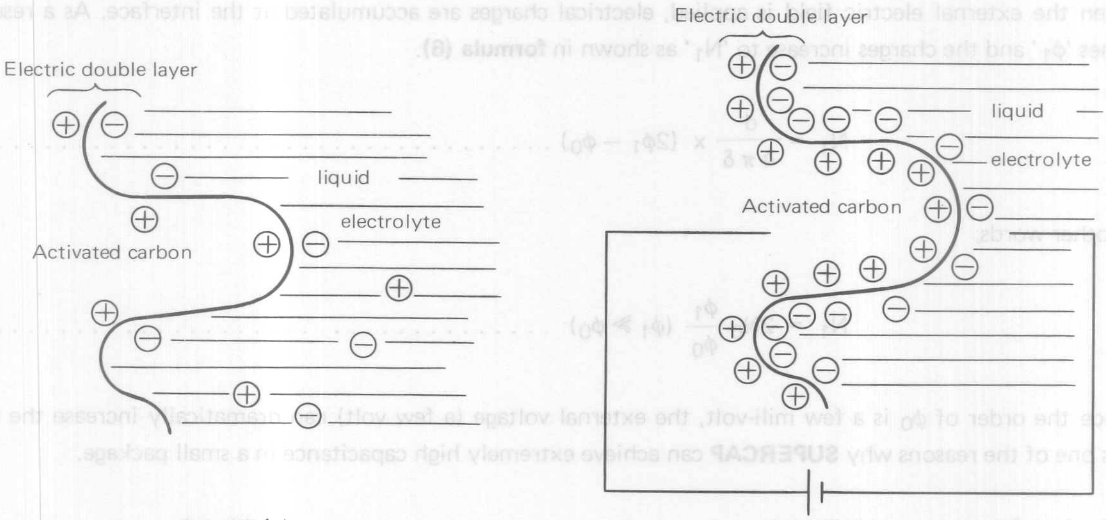


Fig. 39 (a) **Fig. 39 (b)**

Fig. 39 Electric Double Layer

The basic model of **SUPERCAP** is shown in **Fig. 40**.

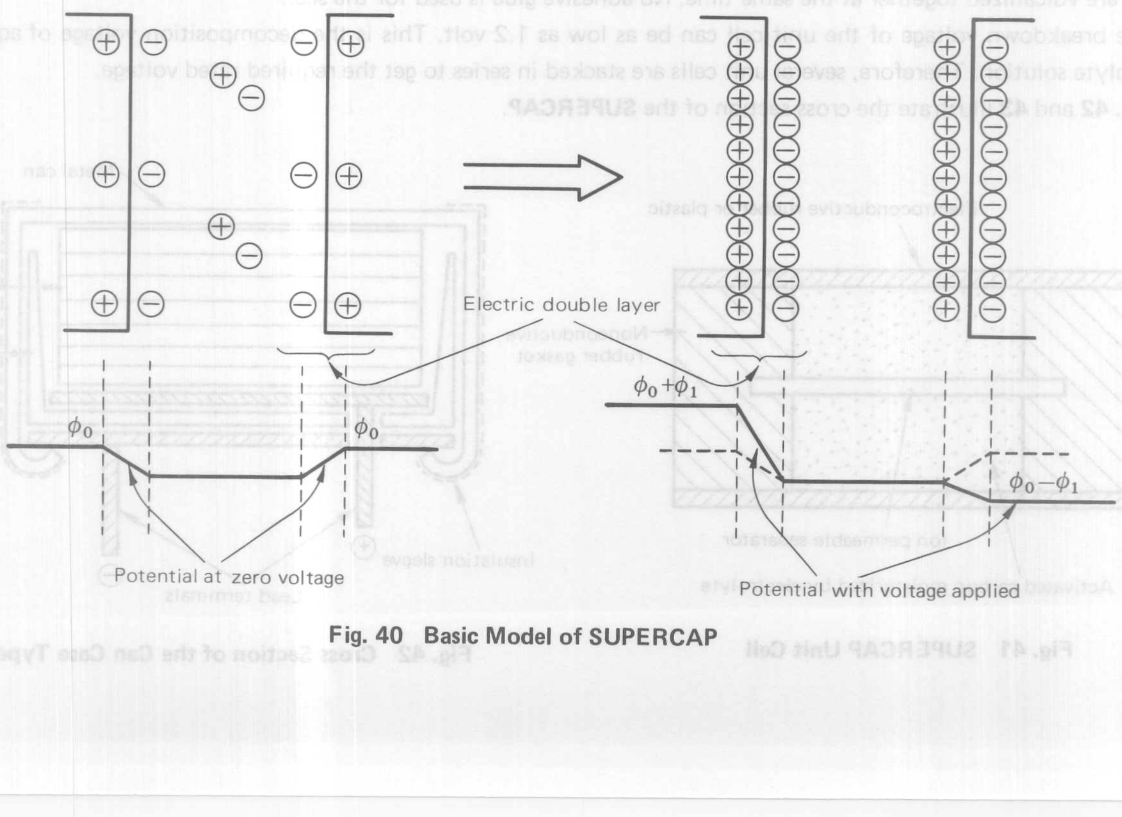


Fig. 40 Basic Model of SUPERCAP

The charges per unit area 'N' is calculated by the **formula (4)**, where 'd' represents a dielectric constant, δ signifies the distance from a solid surface to the center of ions and 'ϕ' represents the electric potential of double layer.

$$N = \frac{d}{4\pi\delta} \times \phi \quad \cdots\cdots (4)$$

In **Fig. 40** if 'ϕ' at the time of no-voltage is 'ϕ_0' then, 'N_0' is shown in **formula (5)**.

$$N_0 = \frac{d}{4\pi\delta} \times \phi_0 \quad \cdots\cdots (5)$$

When the external electric field is applied, electrical charges are accumulated at the interface. As a result, 'ϕ_0' becomes 'ϕ_1' and the charges increase to 'N_1' as shown in **formula (6)**.

$$N_1 = \frac{d}{4\pi\delta} \times (2\phi_1 - \phi_0) \quad \cdots\cdots (6)$$

In other words;

$$N_1 = 2N_0 \frac{\phi_1}{\phi_0} \quad (\phi_1 \gg \phi_0) \quad \cdots\cdots (7)$$

Since the order of ϕ_0 is a few mili-volt, the external voltage (a few volt) can dramatically increase the charges. This is one of the reasons why **SUPERCAP** can achieve extremely high capacitance in a small package.

6.2 Product Structure

The cross section of a unit cell is shown in **Fig. 41**. The activated carbon particles moisturized (not in real liquid state) by diluted sulfuric acid electrolyte are segregated by a porous, ion permeable separator, and packaged inside by electroconductive rubber and nonconductive rubber gasket.

The unit cell is hermetically sealed by the electroconductive rubber and nonconductive rubber gasket, both of which are vulcanized together at the same time. No adhesive glue is used for the seal.

The breakdown voltage of the unit cell can be as low as 1.2 volt. This is the decomposition voltage of aqueous electrolyte solution. Therefore, several unit cells are stacked in series to get the required rated voltage.

Fig. 42 and **43** illustrate the cross section of the **SUPERCAP**.

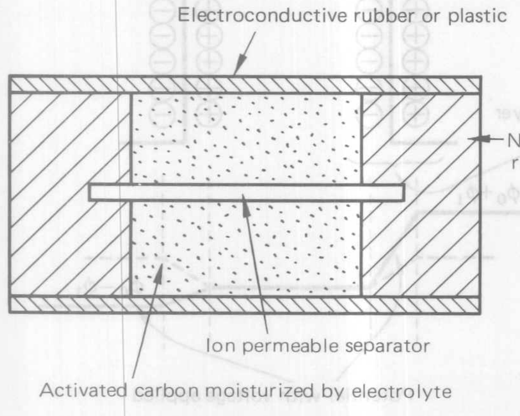


Fig. 41 SUPERCAP Unit Cell

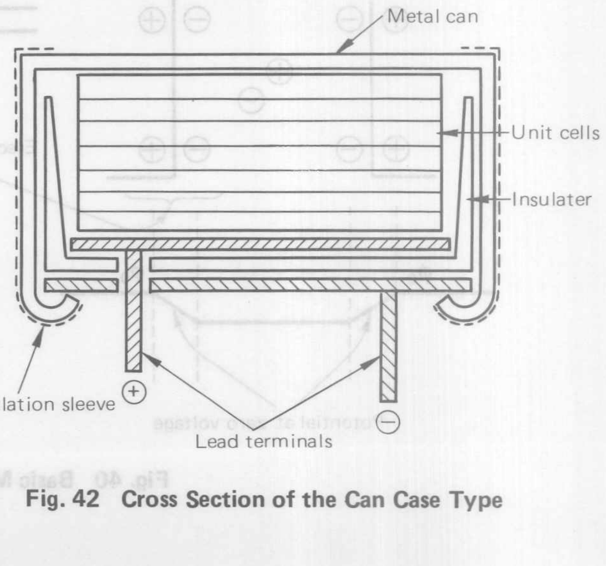


Fig. 42 Cross Section of the Can Case Type

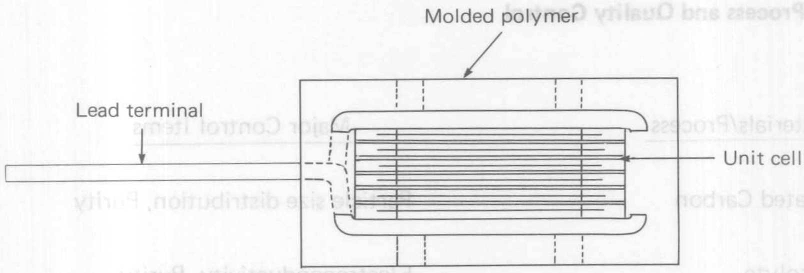


Fig. 43 Cross Section of the Molded Type (FM Series)

[Note] Activated carbon is specially processed carbon to achieve very high porosity, so that its surface area is greatly increased. This feature is widely utilized as an odor absorption material. **SUPERCAP** also utilizes its wide surface area for the high capacitance electrode.

6.3 Manufacturing Process and Quality Control

- Can Case Type

Materials/Process	Major Control Items
Activated Carbon	Particle size distribution, Purity
Electrolyte	Electroconductivity, Purity
Mixing	Mixing Ratio
Electroconductive Rubber	Electroconductivity, Mechanical strength
Nonconductive Rubber Gasket	Mechanical strength
Ion Permeable Separater	Mechanical strength
Unit Cell Assembly	Ambient (Temp, Humidity) conditions
Vulcanization	Vulcanization Temperature
Finished Unit Cells	Hermeticity
Series Stacking of Unit Cells	Stacking Pressure, Outlook
Metal Can, Insulator, Leads, etc.	Outlook, Dimensions, Plating thickness
Casing and Caulking	Caulking pressure, Dimensions
Insulation Sleeve (Marking)	Dimensions, Outlook
Sleeving	Outlook, Oven temperature
100 % Burn-in	Voltage, Time, Oven temperature
100 % Inspection	Capacitance, ESR, Charging Current Voltage holding characteristics (FR, FY Series), Dimensions
Outgoing Inspection (sampling)	Capacitance, ESR, Charging Current Voltage holding characteristics (FR, FY Series), Dimensions

- Molded Type (FM Series)

Materials/Process	Major Control Item
Activated Carbon	Particle size distribution, Purity
Electrolyte	Electroconductivity, Purity
Mixing	Mixing Ratio
Electroconductive Rubber	Electroconductivity, Mechanical strength
Nonconductive Rubber Gasket	Mechanical strength
Ion Permeable Separator	Mechanical strength
Unit Cell Assembly	Ambient (Temp., Humidity) conditions
Vulcanization	Vulcanization Temperature
Finished Unit Cells	Hermeticity
Series Stacking of Unit Cells	Stacking Pressure Outlook
Lead Terminals	Dimensions, Plating thickness
Molded	Outlook, ESR
Marking	Temperature, Outlook
100 % Burn-in	Temperature, Voltage, Time
100 % Inspection	Capacitance, ESR, Charging Current, Voltage holding characteristics, Dimensions
Taping	Outlook, Dimensions
Outgoing Inspection (sampling)	Capacitance, ESR, Charging Current Voltage holding characteristics, Dimensions